WATER AVAILABILITY UNDER CLIMATE STRESS IN A HILLY SETTLEMENT OF NEPAL: A CASE STUDY FROM TANSEN, PALPA

A Dissertation Submitted to

CENTRAL DEPARTMENT OF ENVIRONMENTAL SCIENCE
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

In Partial Fulfillment of the Requirements for the Award of Degree of M.Sc. in Environmental Science

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October, 2017

DECLARATION

I hereby declare that the work presented in this dissertation is a genuine work done originally by me and has not been submitted anywhere for the award of any degree. All the sources of information have been specifically acknowledged by reference to author(s) or institution(s).

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RECOMMENDATION

This is to certify that **Ms. Ashmita Paudel** has completed this dissertation work entitled **"Water Availability under Climate Stress in a Hilly Settlement of Nepal: A Case Study from Tansen, Palpa"** as a partial fulfillment of the requirements of M.Sc. in Environmental Science under our supervision and guidance. To our knowledge, this research has not been submitted for any other degree, anywhere else.

We therefore, recommended the dissertation for acceptance and approval.

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LETTER OF APPROVAL

On the recommendation of supervisors "Dr. Dinesh Raj Bhuju" and "Dr. Giovanna Gioli" this dissertation submitted by **"Ms. Ashmita Paudel"** entitled **"Water Availability under Climate Stress in a Hilly Settlement of Nepal: A Case Study from Tansen, Palpa"** has been approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements of M.Sc. in Environmental Science.

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CERTIFICATE OF ACCEPTANCE

This dissertation entitled **"Water Availability under Climate Stress in a Hilly Settlement of Nepal: A Case Study from Tansen, Palpa"** by **"Ms. Ashmita Paudel"** has been examined and accepted as a partial fulfillment of the requirements of M.Sc. in Environmental Science.

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Central Department of Environmental Science for providing me the opportunity to conduct this research.

I would like to acknowledge the financial support I received from HI-AWARE (Himalayan Adaptation, Water and Resilience) project to carry out this research during my two-year course.

I am extremely thankful to my supervisor Academician Dr. Dinesh Raj Bhuju for his tremendous support, persistent guidance and encouragement throughout the research, without which the study would have been incomplete. My sincere gratitude also goes to my supervisor from ICIMOD, Dr. Giovanna Gioli for her immense support, and noble guidance.

I would like to take this opportunity to thank Prof. Dr. Kedar Rijal (Head of Department) for providing me the support and the opportunity to conduct this research. I would also like to thank Dr. Sudeep Thakuri for supporting the research processes.

I am grateful to ICIMOD (International Centre for Integrated Mountain Development), especially the HI-AWARE team from whom I have learned the basics of carrying out field research on various occasions. I am indebted to Ms. Krity Shrestha from Practical Action, Nepal whose help and support throughout the planning phase of this research has been commendable.

I am thankful to the people of Tansen for trusting me with information. Special thanks goes to Ms. Sushila Magar for facilitating the research, Er. Keshab Lal Shakya and Mr. Chakorman Shakya for providing me with the data and information needed.

Finally, I would like to thank all my friends who helped me by providing me their valuable time and opinion to prepare this report. I would like to express my sincere thanks to my parents, my brother Animesh Paudel, sister Smritee Paudel and friend Abhaya Raj Joshi for their support, encouragement and motivation throughout the research.

Ashmita Paudel
25th August, 2017

ABSTRACT

Only two-and-a-half percent of the water available on earth is freshwater. Thirty percent of the total volume of freshwater on earth is groundwater. Groundwater sources are massive but finite. Many human settlements around the globe are dependent on groundwater. The predicted climate change will exacerbate this concern by reducing precipitation and increasing evapotranspiration, both of which will reduce recharge and possibly increase groundwater withdrawal rates. This, however, is in want of empirical data from many sites as possible. This research study takes the case of the Tansen municipality, a mountain settlement in Palpa district of west Nepal to evaluate the water demand and supply in the area. It attempts to analyze the trend of climate change in Palpa for the last three decades, and the trend of groundwater recharge through rainfall using Mann-Kendall tests. Underlying management and governance of the local water users' committee have been studied to assess its role in determining the water availability in Tansen by the measures of schedule survey, Key Informants Interview (KII) and Focus Group Discussions (FGDs). The study found that the rate of temperature increase in the study area is 0.087°C per year with 5% level of significance and 95% confidence interval. Rainfall pattern and recharge rate did not show a significant trend. Total water demand and supply for Tansen municipality were found to be 2,926,000 liters and 840,000 liters per day respectively. The per capita demand and supply were found to be 283.19 liters per day and 81.3 liters per day respectively. The committee was found to follow both top-down and bottom-up approach in taking decisions where necessary. Participation was found to be encouraged; however, the gender and caste played an important role in involvement, perception and awareness. Lack of proper management for the protection of water sources, insufficient financial and technical capacities and incompetent pricing mechanisms were identified as major causes of the water scarcity in Tansen.

Keywords: *Drinking Water User Committee, Governance, Groundwater recharge, People's perception*

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ABBREVIATIONS AND ACRONYMS

ADB:	Asian Development Bank
APN:	Asia Pacific Network
BCAS:	Bangladesh Centre for Advanced Studies
CBS:	Central Bureau of Statistics
CDO:	Chief District Officer
DDC:	District Development Committee
DHM:	Department of Hydrology and Meteorology
DWSS:	Department of Water Supply and Sewerage
EIA:	Environmental Impact Assessment
ENSO:	El-Nino Southern Oscillation
FGD:	Focus Group Discussion
FNCCI:	Federation of Nepalese Chambers and Commerce Industry
GPS:	Global Positioning System
HH:	Household
HI-AWARE:	Himalayan Adaptation, Water and Resilience
ICIMOD:	International Centre for Integrated Mountain Development
ICWE:	International Conference on Water and Environment
IEE:	Initial Environment Examination
IPCC:	Intergovernmental Panel on Climate Change
MoE:	Ministry of Environment
MK-test:	Mann-Kendall Test
NCVST:	Nepal Climate Vulnerability Study Team

OECD:	Organization for Economic Cooperation and Development
PAN:	Practical Action Nepal
PRSP:	Poverty Reduction Strategy Paper
SPSS:	Statistical Package for Social Science
TDWUC:	Tansen Drinking Water Users' Committee
UC:	User Committee
UNCED:	United Nations Conference on Environment and Development
UNDP:	United Nations Development Program
UNESCO:	United Nations Educational, Science and Cultural Organization
VDC:	Village Development Committee
WBSCD:	World Business Council for Sustainable Development
WHO:	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background

1.1.1 Climate Change and Water Resources

In general terms, climate change is the alteration in weather patterns along with time. The temporal scale for assessment of climate change is considered to be large, i.e. hundreds to thousands of years. Over a shorter scale, for example, less than three decades, the change in climatic phenomenon is called climate variability. Although change of climate is natural and occurs because of fluctuation in solar radiation, atmospheric conditions, biotic processes and volcanic activity, the increasing concerns over it have been raised because anthropogenic influences have accelerated the natural process. Scientific studies after the mid- twentieth century have revealed that the likely cause of the alarming conditions could be human activities attributed to massive industrialisation after the World Wars. “Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.” (IPCC, 2007). Climate variability refers to variations in the mean state of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may occur because of natural internal processes within the climate system (called as internal variability), or due to variations in natural or anthropogenic external forcing (called as external variability) (IPCC, 2001a).

Concerns have been raised not just about the causes of unprecedented global change but also about its effects on various physical, biological and socio-economic systems of the earth. Effects such as the decline in snow cover and glacier and sea ice increments in sea level and rise in surface and ocean temperature and the acidification of oceans have been the subject of studies all over the world. One such effect could be the change in volume of groundwater because of erratic precipitation and decline in the rate of groundwater recharge through rainfall.

Water resources are the source of water that are usable or have a potential use value. Only two-and-a-half percent of the available water on the earth is freshwater. Freshwater is an essential source of water for all living beings. Humans, require freshwater not only for drinking and household purposes but also for agricultural, commercial, industrial activities. Groundwater is the water present beneath the surface of the earth, held by soil or by rocks in their pores and fissures. It is found in enormous quantities among soil or rocks. Only 2.5% of the total water available on earth is freshwater, 30% of the total freshwater is groundwater, whereas only 1.2% of the total freshwater is surface-water. (Shiklomanov, 1993), but only 0.5% of the total freshwater is usable. Although the movement of groundwater is different from that from surface-water, it has a slow motion through the aquifers. In many places, groundwater is the only available source of water. Various towns, cities and villages are dependent on groundwater as their major element of functioning, especially in dry places that do not have other water sources.

Groundwater sources are massive but finite. When the extraction rate exceeds recharge rate, they are likely to become depleted. Groundwater volume in the upper two km of the earth is 22.6 million km^3, about 30-40% of that volume is less than 50 years old (Gleeson et al., 2016). This volume of groundwater, less than 50 years old, or modern groundwater, is most vulnerable to global change because it is the most widely extracted due to its easy access and is more readily exposed to human contamination (Gleeson et al., 2016).

According to OECD projections, water demand is expected to rise by 55% by 2050 and over 40% of the total world population is expected to suffer from severe water stress (OECD, 2012). With the rate of groundwater withdrawal higher than its recharge, its exhaustion has occurred at a rate that has more than doubled between 1960 to 2000-- the increment in demand for manufacturing, electricity and domestic use being the major reasons (OECD, 2012). Water is a multi-sectoral segment that associates across spatial and temporal scale connecting places and people. Policies related to water are of complex nature because of they include aspects such as ecology, health, agriculture, industrial development and poverty alleviation. However, management of water is an essential concern. Involvement of stakeholders that are directly or indirectly linked to the water facilities, redressal of concerns of interested parties, and linkage between different sectors are important in managing available freshwater resources (OECD, 2015).

1.1.2 Governance

Governance is the process of directing, managing and interacting to facilitate decision-making or establishment of policies. Implementation and monitoring of these decisions and policies fall under governance, which might be handled by the governing body of formal or informal organisation or realm. It is the exercise of power vested upon a body by the government. According to Water Governance Facility (2017), "Water governance refers to the political, social, economic and administrative systems in place that influences water use and management. Essentially who gets what water, when and how, and who has the right to water and related services, and their benefits".

Water is a common pool resource in the most basic sense, but the ownership of water resources differs across political and administrative boundaries. In some states, water is owned by the government, whereas in others the ownership of water goes to the land-owner (Pereira et al., 2002). Under the effects of climate change, the role of global water supply is specifically important to ensure food security (Hanjra & Qureshi, 2010). The importance of appropriate management of groundwater as an adaptation technique has been listed in various literature (Green et al., 2011; UNESCO, 2004). Management of groundwater should not just be concerned with the management of quantity to match the supply with demand, but should also cover the aspects of maintaining water quality (UNESCO, 2004). It has been identified numerous times that the issues with groundwater development as a major source of water is not merely technical, but more managerial and administrative (UNESCO, 2004; Bhandari & Grant, 2007). One of the major issues with groundwater management is the involvement of a large number of actors and stakeholders, who have their own specific interests. Agencies and societies which hold the right to use groundwater have different concerns than that of the end-user, which in turn are entirely different from the actors and policymakers. The features of the stakeholders determine how decisions are made and implied for the management of water (UNESCO, 2004).

1.1.3 Tansen Drinking Water Users' Committee (TDWUC)

The first water supply project in Tansen was Banjha project which supplied water to a limited area of Tansen before it was declared a municipality. It consisted of 17 public taps and had the capacity to provide 150,000-160,000 liters water per day. The facility, which is almost 100 years old, was designed to meet the water demand of 12,000 people. This system is almost non-functional now because of source depletion, maintenance issues and high repair cost. Later, the government recognised the growing water demand in the area due to population pressure, but it had limited options for water supply. To provide enough water to residents of Tansen, other sources were integrated into the existing system. The first source to be thus integrated was Bhulki spring, which had the capacity of providing 1,500,000 liters per day. This project was completed in 1978/79 and was run by the government (municipal body) until early 2000s. Finally, under the Water Resources Act, 1992, it was handed over to the user committee by DWSS in 2010. Currently, the system consists of five major sources: Banjha, Bhulki, Sisne, Holangdi and Teendhara. The Bhulki system supplies 600,000 to 1,100,000 liters, Sisne supplies 400,000 to 600,000 liters, Holandgi supplies 200,000 liters and Teendhara supplies 100,000 liters per day. During the pre-monsoon season, the supplies plummet.

The geographical location of Tansen makes it difficult to develop other sources of water. Situated at an altitude of 2,000 meters above sea level (masl), this hill-station does not have rivers or streams. The most feasible point on the nearest river, The Kaligandaki, lies 7 km away from Tansen and on a significantly lower altitude, therefore water would have to be pumped in numerous stages. Even if Kaligandaki were used as a source, lifting of water is expensive.

1.2 Rationale

A considerable number of households in the rural areas of Nepal depend on spring-water for their livelihoods (CBS, 2014; Poudel & Duex, 2017). Difficult terrain and long walking hours to reach the nearest source of water are common issues in the villages of Nepal. Despite the dependence of people on naturally recharged springs, the change in sources of groundwater (Doll & Florke, 2005; Chen at al., 2004) and increased demands due to population pressure hint at a grim future.

The evidence of climate variability in Nepal can be found in various literatures. Increase in temperature is found to be more prominent in the higher altitudes in Nepal and the warming is more distinct in winter than in any other seasons (Shrestha & Shrestha, 2005). It has also been noted that the differences in temperature are most noticeable in dry winters and least noticeable during the monsoon (Bajracharya et al., 2011). The findings are supported by Goswami et al. (2006) which conclude that rainfall caused by the Indian monsoon has become quite unstable with increasing magnitude of extreme events of precipitation. There is more intense rainfall in short span of time and decline in the winter rainfall, which causes more water to runoff and undergo evapotranspiration and less to infiltrate (Jykarma & Sykes, 2007). As a result, groundwater sources are depleted.

Water is an integral part of livelihoods in the Himalayan towns and villages. Although majority of the uses of water are small-scale- domestic and irrigation purposes that are drawn from springs and river, these uses are trivial as compared to the potential use of available water (Bandyopadhyay & Gyawali, 1994). However, large-scale management interventions for water are found to be aimed towards the urban (Acharya, 2015) and plain areas (Bandyopadhyay & Gyawali, 1994), rather than in areas where water originates. This leads to a deduction that not enough consideration has been accorded to the dynamics of rural water systems (Acharya, 2015). The devolution of power to the local government plays an important role in the management of local resources and the future of these resources (Larson, 2003). Although it can be asserted that decision-making at the local level is directly interlinked with the issues and concerns of the people who depend on the resources, often it has been found that depoliticising the process tends to disconnect the management from the grass-root level problems such as power-dynamics and social disparities (DeNeufville & Barton, 1987).

At present, Tansen Water User's Committee has 2,800 users, with a total daily demand of 3,500,000 liters of water. It uses five major sources for supplying water, all of them are groundwater sources and undergo seasonal fluctuation. During the dry periods, the demand for water exceeds the supply. This has fueled conflict within the committee members and the users. Also, because of the hilly terrain on which the town is located, it is not possible to collect water from all sources at a single central point for supply. For this reason, equal distribution of water among the residents of the different parts of the town is difficult.

1.3 Research Questions

The research questions that were addressed in this study are:

i. What is the status and perception of water availability in Tansen, Palpa?
ii. What is the trend of climate variability in Palpa district?
iii. What is the status of groundwater recharge through rainfall in Palpa?
iv. How does the institutional mechanism of the water user's committee perform to ensure equitable supply of drinking water to the consumers?
v. What are the water supply related laws and policies in Nepal?

1.4 Objectives

The general objective of this study is to understand water availability and its underlying governance in Tansen Drinking Water User Committee under the effects of climate variability in Palpa. The specific objectives are:

i. To analyse the three-decade-long temperature and precipitation trend in Palpa district, Western Nepal
ii. To assess the groundwater recharge by rainfall and calculate local demand and supply of water in Tansen, Palpa
iii. To appraise the underlying governance and management for the distribution of water in TDWUC

1.5 Scope and Limitations

Following are the limitations of the study:

a. The study limits itself to the Tansen Drinking Water User Committee.
b. Not all respondents selected through random sampling were available for interview. Some of the selected households had permanently migrated.
c. Some original documents could not be obtained because they were confidential.
d. Spring-flow could not be measured because major sources were protected with concrete covering.
e. The study does not incorporate water demand, supply and availability for agriculture, commercial and industrial purposes.

CHAPTER 2: LITERATURE REVIEW

2.1 Climate Change

Climate variability is a natural phenomenon, however, the current trend of change in temperature and precipitation is accelerated by human-induced processes. ADB (2009) states that constant rise in global temperature and increase in frequency of extreme weather events are signs that climate has changed in the recent decades. Change in climatic pattern and increase in temperature around the world has been a subject of major concern to scientists and environmentalists. The IPCC fifth assessment report (IPCC, 2013) showed an average global temperature increase of 0.85°C between 1880-2012. In developing countries where the major proportion of people are involved in climate-sensitive sectors for livelihood, the concerns of changing climate and its impacts are particularly higher. These pieces of evidence are recorded more in the Asia and Pacific and the sub-regions in these zones are predicted to get warmer. Further, with Central Asia being the exception, the Asia and Pacific regions expect more precipitation (Asian Development Bank, 2009).

Variations in the long-term surface temperature have shown an increasing trend in the past decades (IPCC, 2013; Hansen & Lebedeff, 1987). Evidence of climate change is observed most strongly in natural processes, such as the changing of precipitation patterns and melting of snow that has altered hydrological cycle (IPCC, 2014a). These changes are projected to decrease the amount of surface-water and groundwater resources in many areas, as a result of which, the competition for water is likely to increase (IPCC, 2014b).

In Nepal, a precise variation of climate occurs from north to south within 200 km. From the Arctic climate in the Himalayan region to the tropical in the Terai, regional climatic difference is chiefly a function of elevation (OECD, 2003). Rainfall in Nepal varies according to altitude. Although the average annual precipitation is 1500mm, high-altitude areas above 3,000m experience abundant drizzle whereas lower areas below 2000m experience frequent heavy downpours (OECD, 2003). Monsoon in Nepal generally arrives between 10-12 June, however the monsoon in 2009 entered Nepal from the eastern part on 23 June (DHM, 2009). Analysis of precipitation records from 78 stations from 1948 to 1994 showed no distinct long-term trends in precipitation despite showing some annual and decadal variability (Shrestha et al., 2000).

Temperature trend analysis show an increasing trend (Synott, 2012; Shrestha et al., 1999, MoE, 2010). Synott (2012) showed an increase of 1.8°C between 1975 and 2006, Shrestha et al., (1999) noted an increase of 0.06°C to 0.12°C per year whereas MoE (2010) reaffirmed that the temperature was rising at the rate of 0.04-0.08°C per year. Accordingly, another study of temperature trend of 49 stations from 1977 to 1994 revealed the rate of increase as 0.06°C per year (Shrestha et al., 1999), which is more likely to happen at higher elevations than the lower elevation area. Another study by PAN (2009) analyzed temperatures of 44 stations (1976-2005) showed a lower rate of increase (0.04°C) per year. Monthly variability of runoff is high in Nepal, change in climatic conditions could shift the peak discharge a month earlier than usual (August to July) as a result of which, variation in water availability could be more enhanced throughout the year (BCAS, 2005).

2.2 Groundwater

Groundwater is the largest reserve of freshwater on earth. Although the total amount of water that can be extracted is little, groundwater plays a vital role in sustaining ecosystems. Groundwater is extracted extensively in many countries, where other sources of water are scarce. It is the major source of drinking and domestic water in many countries across the world. In the USA, more than 75% of the municipal water supply systems uses groundwater (UNESCO, 2004). But if used properly, the available sub-surface volume of water could meet the agricultural, industrial and domestic demands across the world (Green, et al., 2011).

In the past, when municipal development began around the world, rivers and springs were considered the primary source of water. But because of ease of extraction, surface water was used more intensively than groundwater. The present scenario, however, shows that groundwater use is increasing as the preferred choice among cities owing to the pollution of surface water sources and spreading of various water-borne diseases (UNESCO, 2004). The widespread use of groundwater can also be attributed to the fact that it is considered as enormous natural storage of water which can be used even during the times of low water availability (Doll, 2009). The extraction rate of groundwater is very high. It is known to possess better quality since it is protected from the sources of pollution. Unlike surface water, there is less fluctuation in the availability of groundwater spatially and temporally. In 2004, UNESCO published in one of their books that the current usage of groundwater can be broken down into: drinking water (65%); irrigation and livestock (20%), industry and mining (15%) (UNESCO, 2004). Whereas, the usage in 2012 was found to be 36% for domestic purposes, 42% for agricultural and 27% for industrial purposes (Taylor, et al., 2012). In Nepal, 756 million cubic meters of groundwater is used for irrigation and 297 million cubic meters is used for domestic purposes (National Water Plan, 2005).

Groundwater use and extraction varies in different settings. The economic scale of extraction is different for various socio-economic characteristics of the users. Because of its open access nature, individuals can extract groundwater for their household uses. Often, water is supplied in a community level or by distributors to consumers, in which case the extraction and distribution processes and costs are managed by the consumers or the intermediate distributors (UNESCO, 2004). Although it is important to understand the hydrological processes of groundwater and estimate appropriately groundwater levels for future considerations, measuring the recharge of groundwater is not an easy task since direct measurements of groundwater recharge is not available (Doll & Florke, 2005). Lack of technical measures for groundwater studies to quantify recharge rate and groundwater levels, quality monitoring and control also add to the problems of managing groundwater (UNESCO, 2004).

Measurement and quantification of groundwater recharge by natural process is a difficult task. It holds a high importance in efficient management of aquifers, but is subjected to errors and uncertainties (Kumar & Seethapathi, 2002). For many decades, groundwater has been studied by analyzing the components of surface runoff from hydrographs (L'vovich, 1979). Integrating the hydrographs with temperature and precipitation data can make this process somewhat easier for hydrologists, but the lack of detailed and regular hydrological data that can be used as reliable estimates for studying groundwater processes are not maintained in many countries (L'vovich, 1979).

Based on the amount of rainfall and fluctuation of rainfall, Chaturvedi developed an empirical formula for groundwater recharge through rainfall in 1973.

$R = 2.0 (P - 15)^{0.4}$ (Chaturvedi, 1973)

where,

R = Recharge due to precipitation

P = Annual Precipitation

This has been used extensively as a basis for the preliminary appraisal of groundwater recharge through rain. This formula was later modified by the Irrigation Research Institute, Roorkee to decrease the errors and uncertainties:

$R = 1.35 (P - 15)^{0.5}$, where R and P are the same

Later, Kumar and Seethapathi (2002) studied the groundwater balance for Upper Ganga Basin and calculated the recharge coefficient. While comparing the relative error from Chaturvedi's formula and their new proposed formula, it was found that Chaturvedi's formula had an error as high as 66%, whereas the new proposed formula had a relative error as high as 7.8% for Upper Ganga Basin (Kumar & Seethapathi, 2002). The new formula was derived by fitting the rainfall values with their corresponding estimated values of recharge:

$R = 0.63 (P - 15.28)^{0.76}$

where,

R = Recharge due to precipitation, and P = Annual Precipitation

2.2.1 Climate Change and Groundwater

The impacts of climate change on freshwater are not certain. It could increase the amount of rainfall and hence freshwater availability in some parts of the world. Whereas, it could also increase the rate of evapotranspiration and decrease freshwater. Also, the rainfall might occur in the form of storms that cause flooding and do more damage (WBSCD, 2009). Groundwater can be linked to climate change through its direct and indirect interaction with surface water (Jyrkama & Sykes, 2007). The impacts of climate change on groundwater have long been established, but the study of impacts of climate change on groundwater is comparatively less (IPCC, 2001b).

One of the issues in assessing the impacts of future change on groundwater recharge is socio-economic uncertainties. Inability to integrate socio-economic scenario into hydrological and land-use models accounts for an incompetent and non-representative result. Many socio-economic factors like pricing and subsidies, changing pattern of urbanization along with temperature and precipitation, agriculture and forest cover changes together account for the impacts in groundwater recharge (Holman, 2006). Many scientific studies have been done to understand the impacts of climate change on groundwater hydrology by developing models based on hydrological processes. Some of these models use spatially distributed approach and regard hydrological processes as constant phenomenon, e.g. Brouyere et al., (2004), whereas some tend to assess the change in groundwater system that is resulted because of decrease in rainfall (Chen & Chen, 2004).

The exact rate of decline in groundwater recharge because of climate change has not been estimated, it shows different trends of increase or decrease for different parts of the world in different climate change scenarios (Brouyere et al., 2004; Chen & Chen, 2004; Doll, 2009). Whereas, other studies have pointed out the limitation of infiltration capacity (Doll & Florke, 2005) and increase in evaporation because of warmer climate (Jykarma & Sykes, 2007) for the limitation of groundwater recharge.

Chen et al. (2004) studied past temperature and precipitation records and linked it with water levels in monitoring wells to understand the impacts of climate change on groundwater. The study indicated that there is a strong correlation between climatic variables and groundwater levels and concluded that increase in mean temperature is more likely to reduce groundwater recharge (Chen at al., 2004). Impacts of climate change on groundwater and vice versa remain as a topic of uncertainty because of lack of knowledge about groundwater and its interactions with the climate (Green, et al., 2011) as well as social uncertainties (Holman, 2006). Estimation of groundwater recharge and quantifying of exact figures can be difficult because of the ambiguity in temporal and spatial scale (Jyrkama & Sykes, 2007). The manifold system of water supply which is rapidly changing and complex in itself makes it challenging to assess the future sustainability of water supply (Vorosmarty et al., 2000).

2.3 Population and Water Demands

Population of the world is projected to reach 8 billion by 2030 and 9 billion by 2050 (WBSCD, 2009). The rate of growth is approximately 80 million people each year. Nepal’s rate of population growth is 1.35% per year (CBS, 2012), whereas that of the world is 1.11% per year. According to the United Nations’ projections, the population of the world could grow anywhere between 7 billion to 10 billion by the end of this century (United Nations Population Division, 2015). With the technological advancement, people’s lifestyles are shifting to more water-demanding ways. Water footprint, which is the amount of total water for producing goods and services consumed by people, differs from country to country. It depends on two factors: amount of consumed water and the water footprints of consumed commodities (Water Footprint Network, 2017). According to Mekonnen & Hoekstra (2011), per capita water footprint of Nepal is 1200-1385 m^3/year and the global average is 1385 m^3/year per capita.

Domestic water demand is influenced by factors such as climate, water related policies, strategies and socio-economic characteristics of a particular area (Babel et al., 2007). The minimum amount of water required per person for bare necessities like drinking and cooking daily is 30 liters. For household maintenance purposes like washing, cleaning and sanitation, an additional 250 liters per person is the minimum requirement (WHO, 2004). In worldwide scenario, the largest amount of water is consumed by agriculture (70%), followed by industrial use (20%) and domestic use (10%). But the figure is not the same for every countries. Developed counties use more water for industrial purposes. In high-income countries, 59% of total water is used for industries, 30% for agriculture and 11% for domestic use whereas in low-income countries the amount is 10%, 82% and 8% respectively (WBSCD, 2009).

Change in lifestyle, feeding habits, energy demands, consumption rate affect water demands. Water demand is also affected by factors such as amount of rainfall, cost of water as well as the education level of public. Development and management of water sources is not efficient without proper demand forecasting. Measures can be taken for demand management, such as encouraging water conservation in household and industrial levels, leakage detection and repair, metering and proper tariff of water facilities, public awareness and participation in water management activities and legal measures like laws and regulations (Babel et al., 2007).

2.4 Governance

According to the United Nations Development Programme, “Governance is the exercise of economic, political and administrative authority to manage a country’s affairs at all levels...it comprises the mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations and mediate their differences” (UNDP, 1997). Whereas, Global Water Partnership defines Water Governance as “the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society" (Global Water Partnership, 2002).

A system of governance must fulfil some necessary criteria to be called as a good system. Transparency, participation, inclusiveness, accountability, responsiveness and predictability are some of the necessary criteria for good governance (Rogers & Hall, 2003). Whereas for water governance, criteria such as cost effectiveness, financing, regulatory framework, integrity, transparency, stakeholder engagement, clear roles and responsibilities and policy coherence are essential for good governance (OECD, 2015). Failure of water governance is caused by inappropriate price regulations and tax incentives, conflicting regulations, over- or under-regulations, lack of independence, monopoly, lack of entrepreneurial incentives, bureaucratic obstacles, lack of knowledge, resource and capacity among many other factors (Rogers & Hall, 2003).

2.4.1 History and Development of Water Governance

United Nations Conference on Water held in Argentina in 1977 recommended that the 1980s should be announced as the International Drinking Water Supply and Sanitation Decade. It highlighted that every person had a right to water in adequate quantity and quality for their survival (World Water Assessment Programme, 2003). This marked the beginning of water related policies in the world. In 1992, International Conference on Water and Environment (ICWE) was held in Dublin, Ireland. It identified the critical need for the management of global water resources issue. Four guiding principles were formulated which were communicated to the world leaders assembled at the United Nations Conference on Environment and Development (UNCED). These principles were very important in identifying the need for water governance. According to the principle no. 2 "Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels" (ICWE, 1992). Integrating the plans of water with sustainable development, the Dublin Principles focused on enabling environment, role of women, economic valuation and capacity building for building action plans for water. In 1992, Agenda 21 of the Rio Earth Summit included the issue of water recognizing that water is a basic facility that should be available to all for sustenance and health and identified a need to develop sustainable water policies to ensure safe drinking water and adequate sanitation for people (UNCED, 1992).

Since then, the importance of water issues has been identified by the international community. The Global Water Partnership Framework of Action held in 2000 in Hague recognized that water crisis is a result of poor governance and the 2000 Hague Ministerial Declaration advised that proper management of water should be done in all scales to ensure the interests of all stakeholders for good governance (Rogers & Hall, 2003). Following The Hague Declaration, Freshwater Conference in Bonn in 2001 proposed for each countries to have their own applicable systems of water governance. In 2002, the World Summit on Sustainable Development acknowledged water management as one of the most prominent issues of the millennium. The Sustainable Development Goals launched in 2015 listed under goal 6, that water and sanitation should be available and sustainably managed for everyone. Likewise, also in 2015, OECD came up with Principles on Water Governance (OECD, 2015).

Many indicators have been given to measure governance. The most widely used is the set of indicators given by the World Bank that comprises of six indicators (Kauffman et al., 2009):

- Voice and Accountability
- Political Stability and Absence of Violence
- Government Effectiveness
- Regulatory Quality
- Rule of Law
- Control of Corruption

However, these are the generalized set of indices. To cope with the challenges of global change, OECD identified a need for strong policies to tackle with water management. By setting measurable objectives at achievable time-scale, OECD Principles on Water Governance (OECD, 2015) contribute to the strengthening of robust water governance. The OECD Principles on Water Governance consists of 3 broad categories: Effectiveness, Efficiency and Trust & Engagement. Each of them comprise of 4 indicators, making it a set of 12 indicators. These indicators are relevant to all levels of government and can be modified to design and implement national policies for specific situations of any country (OECD, 2015).

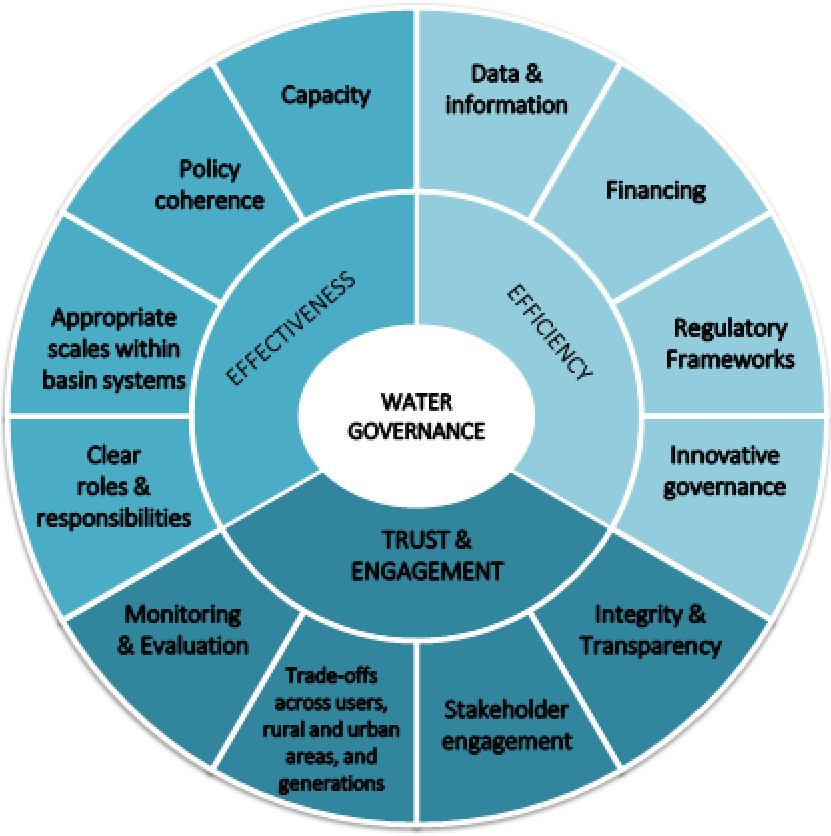

Figure 1: OECD Principles on Water Governance

Source: OECD (2015)

2.4.2 Local Governance of Water Supply

Viable management of water is a crucial issue during this period of global change (Pahl-Wostl et al., 2010). Often, adequate supply of water is not just the outcome of insufficient water, but weak institutional and technical capacity, which is often the case in villages of Nepal (Bhandari & Grant, 2007). It has been suggested that the success of a water supply system depends on the consumers' willingness to pay (World Water Assessment Programme, 2003). In Nepal, water is supplied in the rural and semi-urban areas by the efforts of Governmental, Non-Governmental and International Non-Governmental organizations. Especially in the rural settings where people are not economically well-off to pay for water supply, the role of these organizations is more pronounced. The technical and infrastructural aspects of supply, decentralization of resources and provision of subsidies and rewards and reduction in corruption could lead to the success of the water supply system (World Water Assessment Programme, 2003). Water allocation and use are governed by a set of rules and policies, which although are not perfectly applicable for all situations, determine the efficiency of water use (Pereira et al, 2002).

Decentralization is the process of distribution of power and authority and the dispersal of executive rights to the local bodies to enable them for decision making regarding their local resources. Decentralization increases efficiency by improving the allocation of resources, enhancing accountability and equity (Larson & Soto, 2008). The most common practice of decentralizing water governance is done through the formation of User Groups. Users are the consumers of water who receive water through pipelines at their households or for irrigating their farmlands (Pereira et al., 2002). These groups are also called User Associations, User Committees or Cooperatives and they operate under the guidance of a set of formal or informal rules. Although the organizational framework differs according to the socio-political and legislative situations, they are often vested upon the responsibilities of management, maintenance, revenue collection and financing by themselves (Pereira et al., 2002). The formation of user groups is also essential to integrate the interest of users and public into the water governance. Resources managed by government and municipal bodies are more concerned about the technical aspects of water supply than the common interest of users (UNESCO, 2004).

Nepal's policies and regulations on the management of environmental resources as well as development policies are increasingly focusing on participation and decentralization. Participation depends on social reach and economic status of an individual, and although the policies focus on minority groups, in the case of Nepal, it has been noticed that people with greater access are more likely to understand the decentralization policies and hence are more likely to be the parts of user groups created by the government for resource utilization and mobilization (Agrawal & Gupta, 2005). And although decentralization of power for good governance sounds noble in theory, it is seldom practiced in real. The reluctance of the central government to hand over authority and resources to the local level makes it difficult for a perfect implementation (Larson & Soto, 2008). Local governments are said to be more accountable than unelected authorities, but it can only be concluded under the conditions that the process of election has been fair and the influence of political parties and economic interest are reasonable and they have enough motivation to take initiatives for the better of local people (Larson & Soto, 2008). But local governments are feeble and organizations of civil society often lack a strong base (Rogers & Hall, 2003).

The increasing interest of donor agencies to integrate climate change into their major concerns has led to an increase in incorporation of climate change into development activities. In Nepal, 50-60% of the total national official flows (about $200 million) go to climate change and activities that are affected by climate risks (Agrawala & Aalst, 2008). Nepal has prepared a Poverty Reduction Strategy Paper (PRSP) but the 10th national development plan does not include the risks posed by climate change or risks of climate related phenomenon into development and poverty alleviation (Agrawala & Aalst, 2008). But the 14th Development Plan includes a chapter on Environment and Climate Change and emphasizes on the adaptation to climate change by channeling budgets to development activities which have integrated climate adaptation measures. It also states that a large part of the national budget under the topic of climate change will be spent in the local levels. A commitment to adhere to the international treaties relating to environment has been stated, however the direct impacts of climate change on water resources have not been mentioned (National Planning Commission, 2016). The 13th National Plan of Nepal targeted for 95% people to have drinking water facilities, but only achieved 83.6%. The 14th National Plan targets the figure to reach 90% in 2018/19 (National Planning Commission, 2016).

2.4.3 Relevant Water Related Legislations of Nepal

The major laws and policies related to water as given below:

Table 1: Water Related Legislations of Nepal

Legislation	Key Features
Water Resources Act, 1992	• Major act for the management of water resources • Provision for the formation of Water Users Associations • Priority ranking for the utilization of water resources • Right to utilize or develop water resources lies with the Government despite the ownership • Provisions for penalty and cancelling of license to use • Government of Nepal holds the power to formulate rules regarding the use and conservation of water resources
Water Resource Rules, 1993	• Procedure for the formation and licensing of Water Users Associations

Legislation	Key Features
	• Establishment of the Water Resource Committee • Licensing is done by the Water Resource Committee • Explains the rights and responsibilities of Water Users Associations and license holders
Environment Protection Act, 1997	• Prohibits pollution of water resources • Power to constitute environment protection council and frame rules
Environment Protection Rules, 1997	• Type of water related projects that should conduct Environment Impact Assessment (EIA) or Initial Environment Examination (IEE) • Provisions for pollution control certificate
Drinking Water Rules, 1998	• Establishment and registration of consumer organization • Requirement for the consumer organization to have their own constitution • Deals with the control of pollution to water sources • Provide information on the conditions for utilization of water resources • States the duties of the consumers
Local Self-Governance Act, 1999 & Local Self-Governance Regulation, 1999	• Decentralization in the existing institutional framework of the government • Distribution of authoritative and administrative power to DDCs, Municipalities and VDCs • Provision of Water Resource and Land Committees in bottom levels • Drinking water and sewerage facilities are identified as key components of resource maps • Procedure for formation and implementation of water related plans and projects
Water Resource Strategy, 2002	• Identification of need for comprehensive water resources policy

Legislation	Key Features
	• Formation of short term (5 years), medium term (15 years) and long term (25 years) plan for water supply, environment, irrigation, hydropower, disaster management, international cooperation and institutional mechanisms • Implement equitable mechanisms for sharing of cost • Increase people's access to water through community based projects, rainwater harvesting programs, rural water supply projects
Rural Water Supply and Sanitation National Policy, 2004	• Reinforces National Water Plan and Water Resource Strategy • Encouragement to consumers groups and community organizations to provide water supply and sanitation services • Reinforces water users' rights • Role of DWSS (Department of Water Supply and Sewerage) in facilitating local bodies
National Water Plan, 2005	• Implement and Operationalize Water Resource Strategy • Promote decentralization, integration and participation in local levels • Promote good water governance by encouraging equitable distribution of water • Need for redefining the roles of existing organizations for integrated management of water resources • Identified the role of User Associations for proper management of resources
Constitution of Nepal, 2015	• Right of every citizen to access clean drinking water • Federal power to formulate policies for the use and management of water resources

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and Climate

Tansen Municipality is the administrative headquarter of Palpa District in Lumbini Zone. It falls in the Province no.5 in Western Nepal. Palpa lies on the geographic coordinates of 27°34'N to 27°57'N and 83°15'E to 84°22'E and has an area of 1,373 km^2. Whereas the area of Tansen municipality is 21.72 km^2. The elevation of Palpa varies from 200m to 2000m above sea level (asl), Tansen lying at around 900m asl. The district is bordered by Tanahu and Nawalparasi in the East, Arghakhanchi and Gulmi in the West, Syangja in the North and Rupandehi in the South.

Climate is sub-tropical to upper-tropical with 51.3% lying in upper-tropical Ecological Zone and 47.3% in Sub-tropical Ecological Zone. Temperature varies from minimum 4°C to maximum 37°C. Average rainfall is 1900mm per year. Vegetation is dominated by pine forests, found typical in upper tropical vegetation zone. It consists of 4 seasons: monsoon, post-monsoon, winter-monsoon and dry. Monsoon lies from mid-June to mid-October, Post-Monsoon lies from mid-October to December, Winter-Monsoon lies from January to March and Dry season lies between April and May.

3.1.2 Demographic Profile

Table 2: Demographic Status of Palpa District and Tansen Municipality

Demographic Profile	Palpa	Tansen
Area (km2)	1,373	21.72
Households	59,291	8,433
Total Population	261,180	31,161
Male Population	115,840	15,332
Female Population	145,340	15,829
Average Household Size	4.41	3.70
Sex Ratio	79.7	96.9
Population Density	190	1,435

Source: (CBS, 2011)

Tansen is located on the ridge of Mahabharat Range, forming a small provincial town which has earned its name as one of the most historic hill-stations in Nepal. In the ancient days, it was a "Sen" kingdom, and hence derived its name. In the recent years, it has been one of the most popular tourist destinations for internal as well as external tourists because of its vast areas of pine forests, cool climate, stone-paved pathways up the hill and pollution-free fresh air with potential health benefits. The town is famous for its manufacturing of traditional woven "dhaka" clothes and metal utensils (specially "karuwa"). The majority of people residing in the town are tradesmen, with some large-scale manufacturers with their clientele all over the country and abroad.

Palpa district has a landscape of middle mountains, Churia foothills and floodplains. Geologically, it is constituted of weathered bedrocks, fractures, fluvial sand and gravel aquifers (Bricker et al., 2014). Major sources of surface water are Tinau river and Hulandi river, which flow down the Madanpokhara VDC. Tinau originates from the Mahabharat range, whereas Hulandi from the Siwaliks. Exploitation of groundwater has been done by the use of tube-wells (Bricker et al., 2014).

Table 3: Percentage of Household by Source of Drinking Water in Nepal

Drinking Water Source	Urban	Rural
Tap/Piped	54.9	42.6
Tubewell/Handpump	32.4	37.9
Covered Well	2.9	1.9
Uncovered Well	3.8	6.5
Spring Water	3.7	9.9
River/Stream	0.3	1.3
Others	2.1	0.6

Source: Central Bureau of Statistics (CBS, 2014)

For the purposes of this study, a case study from Tansen Drinking Water User Committee (TDWUC) was taken. This is the major source of water supply for 12 out of 15 wards in Tansen municipality. Although there are other minor user committees spread out in the municipality, they are small groups of around 10-25 households utilizing a minor, local source of water, hence incomparable to TDWUC supplying water to 2,800 consumers.

3.1.3 Map of Study Area

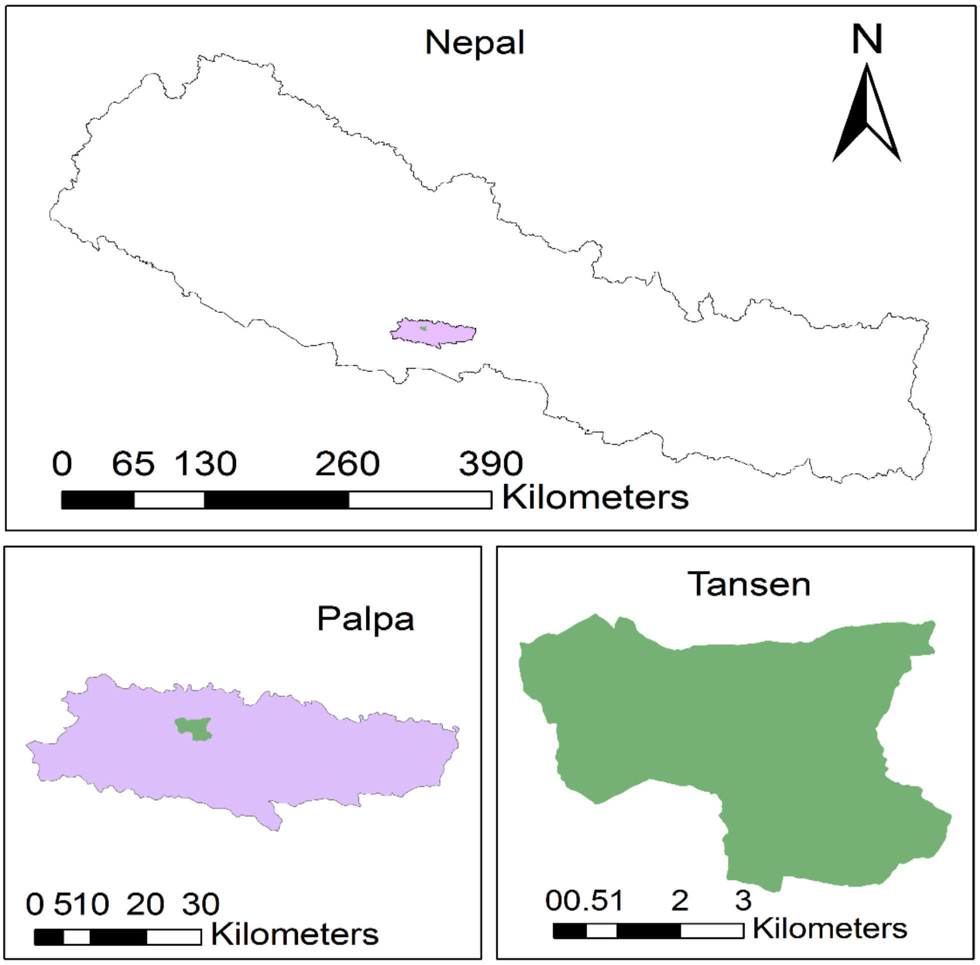

Figure 2: Map of Study Area

3.2 Research Design

The study comprises of both qualitative and quantitative techniques for the collection and analysis of data. Quantitative methods were applied to parts of study where variables were measured quantitatively and information was collected in numerical form. Whereas, qualitative or descriptive information were collected from open ended questions and semi-structured interviews. The research carried out was descriptive, since it included surveys and investigations to find facts about the state of affair.

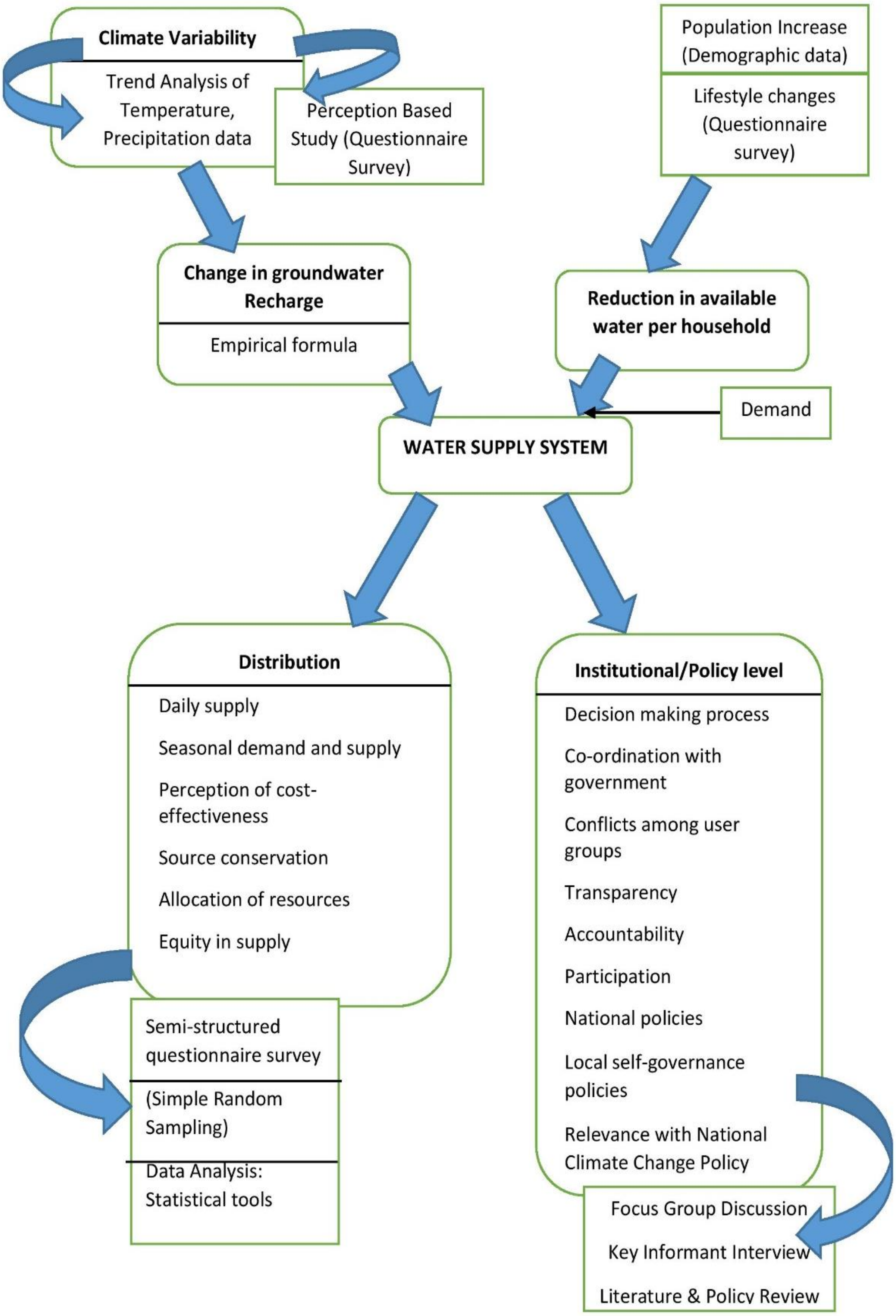

Figure 3: Graphical Representation of Research Design

3.3 Methods

3.3.1 Sampling and Data Collection

3.3.1.1 Primary Data Collection

a. Reconnaissance Survey

A reconnaissance survey was carried out before the actual field work to gain an overview of the study area. Informal interactions were done with the local people, business owners and caretakers of the water sources and executive members of the TDWUC. Information collected during this preliminary survey was used to design the questionnaire for schedule survey and to plan and conduct Focus Group Discussions and Key Informant Interviews. This survey was performed on 13th to 17th January, 2017.

b. Sample Design

The number of samples required for questionnaire survey was determined by Krejcie and Morgan's formula (1970). The total number of consumers registered as users in Tansen Drinking Water User Committee was taken as the population size. Since the area of coverage of municipal water supply was small and the 12 wards did not have distinctive boundaries between them, the population was not stratified into different divisions. Simple random sampling was done by acquiring the list of names of the consumers and using a random number table to select the sample population. Out of the population size of 2800, the required sample size was calculated to be 338 using confidence level of 95% and margin of error 5%.

$S = X^2NP(1-P) / \{d^2(N-1) + X^2P(1-P)\}$ (Krejcie & Morgan, 1970)

Where,

S = required sample size

X^2 = confidence level at 95% ($Z = 1.96$, $Z^2 = 1.96^2 = 3.84$)

N = Population size = 2800

P = Percentage of sample that picks a particular answer = 50% = 0.5

d = degree of accuracy (margin of error) = 5% = 0.05

c. Household Scheduled Survey

Household survey was carried out on 11th April-18th April, 2017. A semi structured questionnaire was used to collect the information about respondents' perception about climate variability, water demand and consumption, functioning and operational procedures of the water user committee and how responsibly and accountably the executive body performs under the stress of increasing water demands. The results from scheduled survey were used to develop an understanding of the governance context. Questions included socio-economic aspects, perception of climate change, involvement in the activities of the user committee and perception about the decision making processes of the user committee. But the calculated sample size could not be met because some of the selected random samples had permanently moved out of the place and some samples are no longer alive.

Considering the heterogeneity of population distribution, the number of randomly selected households taken from each ward are given below:

Table 4: List of Samples for Household Survey

Ward no.	Name of Ward/Tole	No. of Households Selected
1	Mehaldhara	18
2	Badigyan Tole	42
3	Bhimsen Tole	26
4	Bishal Bazaar	36
5	Taksar Tole	10
6	Basantapur	20
7	Kailashnagar	22
8	Bhagawati Tole	39
10	Gairagaun	25
11	Bartung	4
13	Bandipokhara	15
15	Asan Tole	10
	Total	267

d. Focus Group Discussion

Focus group discussions (FGDs) were carried out with the executive body of User Committee, consumer groups and women's groups. It was done after the reconnaissance survey in the first field visit on 13th to 17th January, 2017. Four FGDs were conducted altogether to obtain additional information about the administrative aspect of the user committee, consumers' issues regarding water supply, conflicts of resource ownership and management and governance issues faced by the executive body as well as the consumers. Exercises such as problem identification and prioritization, historical timeline and stakeholder analysis were done during the FGDs.

Table 5: List of Details of Focus Group Discussions

S. No.	Date	Location	Male Participants	Female Participants
1	17th Jan, 2017	Office of TDWUC	10	3
2	18th Jan, 2017	Bartung	11	2
3	18th Jan, 2017	Kunsare	12	5
4	19th Jan, 2017	Office of TDWUC	0	15

e. Key Informant Interview

Informal interviews were done with key informants such as the Chief Officer (Engineer) from DWSS-District Division, Chairman of TDWUC, social mobilizers, caretakers of the water supply facilities, struggle-committee (*sangharsha samiti*), local media group, businessmen and hotel owners to authenticate the information obtained through scheduled survey. Interviewees were asked about the roles and responsibilities of the user committee, managing supply and demand of water in community level, resource and infrastructure management, networking with other stakeholders and their level of engagement and involvement. This provided a detailed understanding of the parameters of the study.

f. GPS Mapping

GPS mapping of the major sources of spring water was carried out on 14th February-19th February, 2017. The major water sources that provides water to the local community were identified, which may or may not be integrated into the municipal water supply system. Minor spring sources providing water to a handful of households were avoided. Data from this survey was used to construct a map of major water sources for Tansen municipality.

g. Literature and Policy Review

Review of relevant literature was done on groundwater, climate change and environmental governance. Relevant national policies and regulations regarding water supply was also done for the purposes of this study. It did not only provide initial contextual information but also created a basis for the assessment of the results of this study.

3.3.1.2 Secondary Data Collection

a. Historical Climate Data

For climate trend analysis, precipitation and temperature data were taken from the Department of Hydrology and Meteorology (DHM). Rainfall data of 28 years (1987 AD to 2015 AD) were taken from meteorological station no. 726 (Garakot, Palpa). 6.07% of the total data were missing, therefore correction was not applied to it. Similarly, temperature data were taken for 27 years (1987 AD to 2014 AD) from meteorological station no. 702 (Tansen, Palpa). More than 20% of the total data was missing, therefore for correction, it was correlated against the data of same time interval from station no. 725 (Gulmi). The corrected data was used for analysis.

b. Groundwater Recharge via Empirical Formula

For the estimation of groundwater recharge through rainfall, an empirical equation given by Kumar & Seethapathi (2002) has been used. This formula is an empirical variation of Chaturvedi's formula (Chaturvedi, 1973). Kumar & Seethapathi's formula has been preferred over the original Chaturvedi's formula because it was found to better represent the study area. Kumar & Seethapathi devised their formula for Upper Ganga Basin, which has a humid-sub-tropical and upper-tropical climate, much like Tansen, Palpa. Assuming a homogenous climatic condition, the average yearly rainfall in Upper Ganga Canal ranges from 550mm to 2000mm while the elevation ranges from 100masl to 7500masl (HI-AWARE, 2017). Tansen, with its elevation from 200masl to 2000masl falls within thin range, and has the average yearly rainfall of 1100mm to 2500mm. The formula that has been used is as follows:

$R = 0.63\ (P - 15.28)^{0.76}$

where,

R = Recharge due to precipitation

P = Annual Precipitation

Recharge coefficients have been defined as the ratio of recharge to rainfall and is calculated as:

Reharge-coefficient = (Recharge/Rainfall)*100%

3.3.2 Data Entry, Analysis and Interpretation

Data obtained through different sources were processed, analyzed and interpreted using software. For climate data analysis, Microsoft Excel 2013 and XLSTAT 2017 were used. Analysis was done using statistical tools such as Pearson's correlation, Mann-Kendall test, time series regression analysis. For the preparation of map of water sources and the map of study area, Arc-GIS 10.2 was used. Likewise, for processing and analyzing socio-economic data, Microsoft Excel 2013, XLSTAT 2017 and IBM SPSS (Statistical Package for Social Science) Statistics 23 were used.

For the analysis of climate trend, Mann-Kendall tests were performed on climatic parameters such as rainfall, maximum temperature and minimum temperature. In case of rainfall, yearly sum of total precipitation was considered, whereas for temperature, yearly average were considered. The Mann-Kendall tests (MK test) were performed with a null hypothesis that there is no trend in the series against an alternative hypothesis that there is a trend in the series. Confidence interval was considered to be 95% and level of significance (ɑ) was considered to be 5%. Hypothesis testing was done by calculating test statistics and p-value. Where p-value was found to be greater than ɑ, null-hypothesis was accepted and vice-versa.

For the analysis of socio-economic data, χ^2 test of independence was used. This test is used to compare two variables to see if they are related or independent. It is a type of non-parametric test which is used for testing the independence criteria of categorical variables. Since it does not assume a normal distribution and is not based on summary statistics of a population (no comparison between means), it is best suited for categorical variables. The null hypothesis for χ^2 test states that there is no association between two variables and the alternative hypothesis states that there is an association between variables. The tests were carried out with 95% confidence interval and 5% level of significance (α). When p-value was found to be greater than α, null-hypothesis was accepted and vice-versa.

3.3.3 Socioeconomic characteristics of sample population

Among the 267 respondents interviewed, the highest percentage of respondents fall in the age group of 50-60 years (28%), followed by 40-50 years (27%), 30-40 years (22%) and 60-70 years (15%). There was a very small proportion of age less than 30 and more than 60.

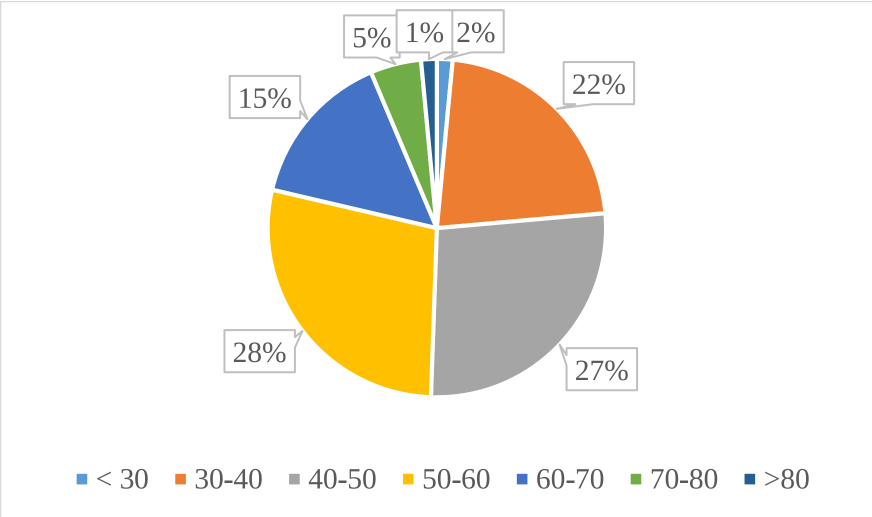

Figure 4: Age-group of Respondents

The percentage of female respondents was found to be higher (52%) as compared to male respondents (48%). Similarly, the highest percentage of respondents were Brahmins (24%), followed by Chhetris (23%), Newars and Magars (21% each), Dalits (6%) and 5% others of Madhesi origins, Thakuris, Muslims. Figure 5 shows the distribution of gender and caste of the respondents.

Accordingly, figure 6 Shows the respondents ward numbers, which relate to the geographical location of their residence. It shows that the majority of respondents are residents of ward number 2, 8 and 4. Whereas, the least number of respondents were from ward number 11, 5 and 15.

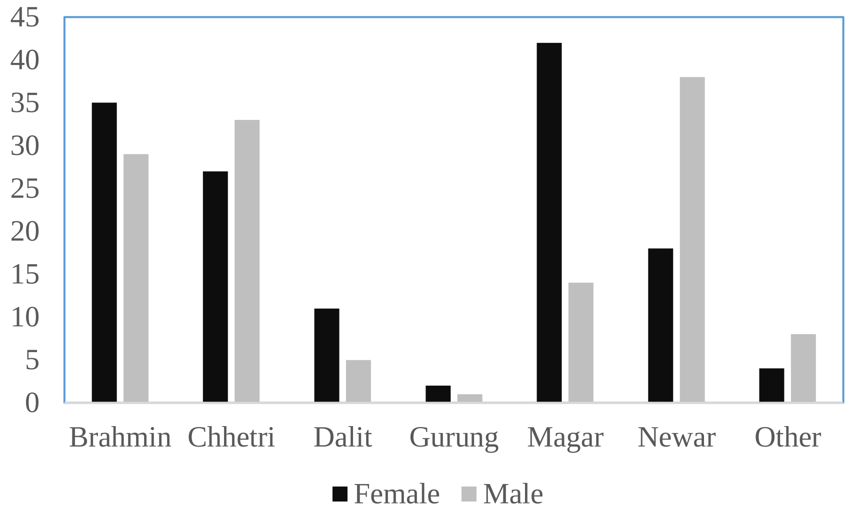

Figure 5: Gender and Caste of Respondents

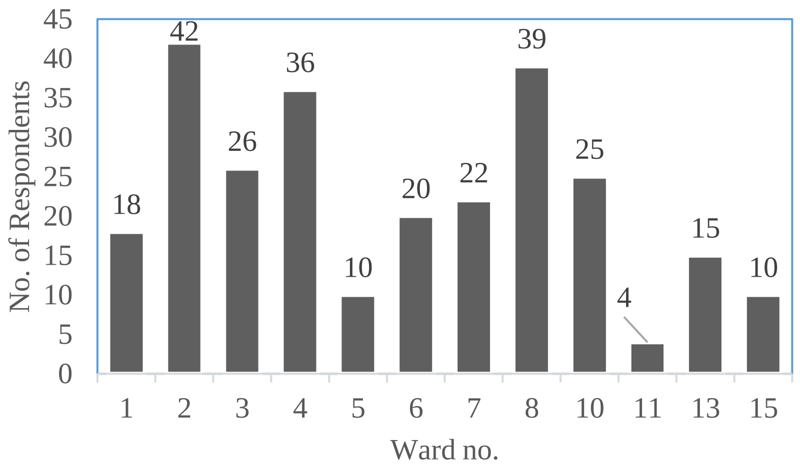

Figure 6: Ward no. of Respondents

CHAPTER 4: RESULTS

4.1 Trend of Temperature, Precipitation and Groundwater Recharge

4.2.1 Rainfall and Temperature Trend

Time series analysis of rainfall of 28 years (1987-2015) from the station of Garakot, Palpa (Station no. 726) is shown in figure 7. Outlier correction has been applied to the rainfall data of 2013 by averaging the preceding and succeeding values. The figure shows that highest rainfall was received in the year 1998 (2676.7mm) and the lowest in the year 2015 (1144.2mm). The average yearly rainfall was found to be 1897mm. The Mann Kendall (MK) test gave a p-value of 0.075, which was found to be greater than the level of significance (0.05), therefore accepting the null hypothesis that there is no significant trend in the series. However, the value of Sen's slope was found to be -13.58, indicating that the decrease in rainfall is 13.58mm/year.

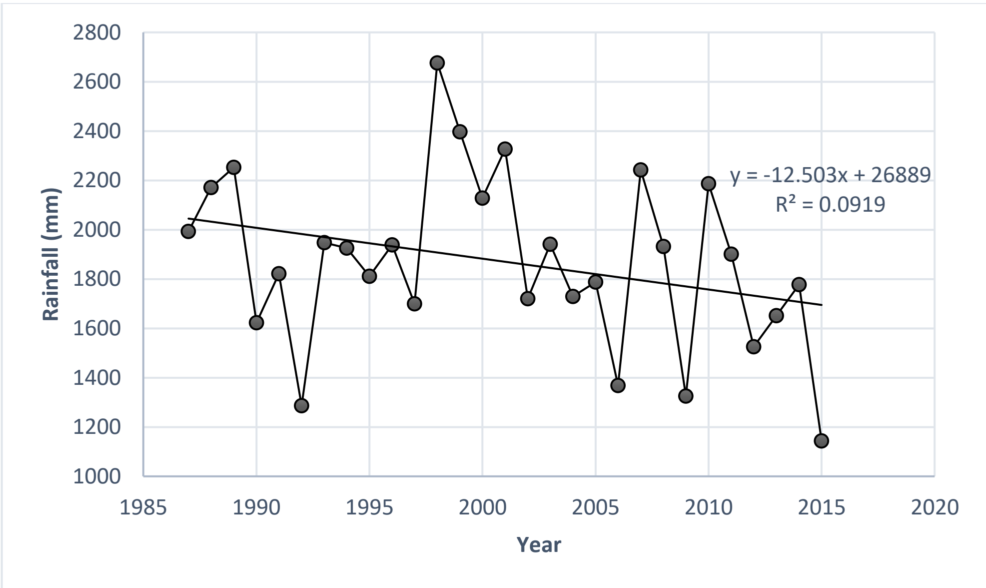

Figure 7: Annual Rainfall for 1987-2015 in Garakot, Palpa

Figure 8 shows the number of rainfall days for 28 years (1987-2015) for Garakot station. The station observed the highest number of rainfall days (122 days) in 2002, and the lowest number of rainfall days (60 days) in 2012.

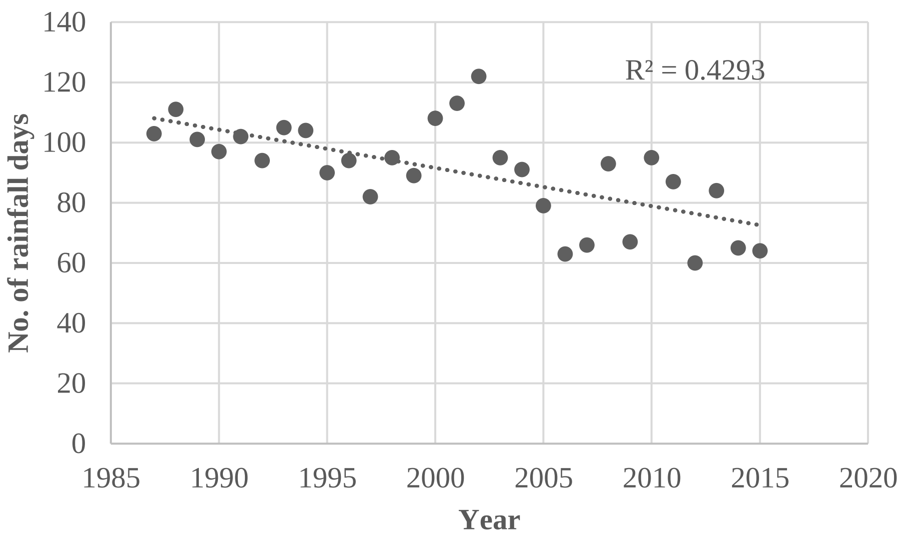

Figure 8: Number of Annual Rainfall Days in Garakot station, Palpa (1987-2015)

Figure 9 shows the monthly average of rainfall for 28 years (1987-2015) for the station of Garakot, Palpa. Highest rainfall is received during the month of July, which is also the mid-monsoon season for Nepal, followed by June and August. Whereas the lowest rainfall is received in the month of November, followed by December and January. The average monthly precipitation is 8.52mm in November to 544.89mm in July.

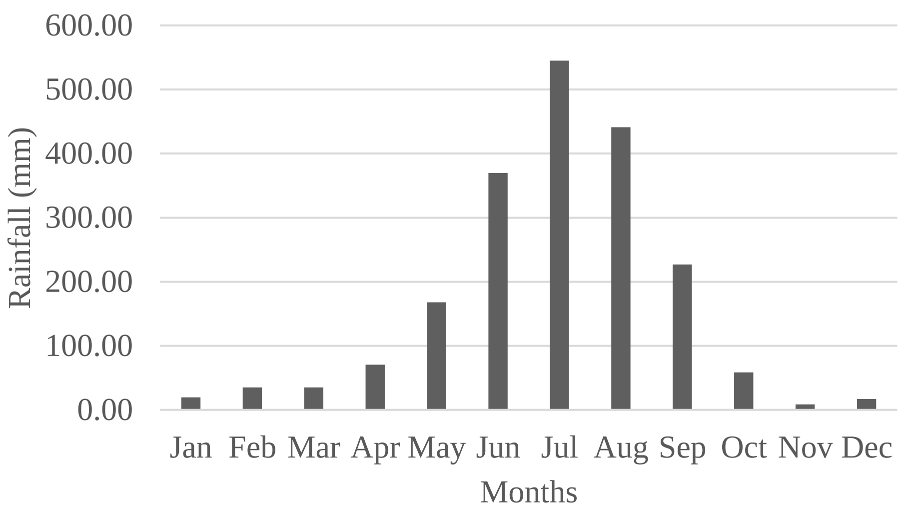

Figure 9: Average Monthly Rainfall (1987-2015) in Garakot, Palpa

For the purpose of this study, 4 classifications of seasons are made: A) Winter: Jan-March, B) Pre-Monsoon: April-May, C) Monsoon: June-September and D) Post-Monsoon: October-December. Highest rainfall is received during Monsoon season, with an average value of 1493.41mm and the lowest rainfall is received during Post-Monsoon with an average value of 79.6mm which is closely followed by winter with average precipitation of 84.68mm.

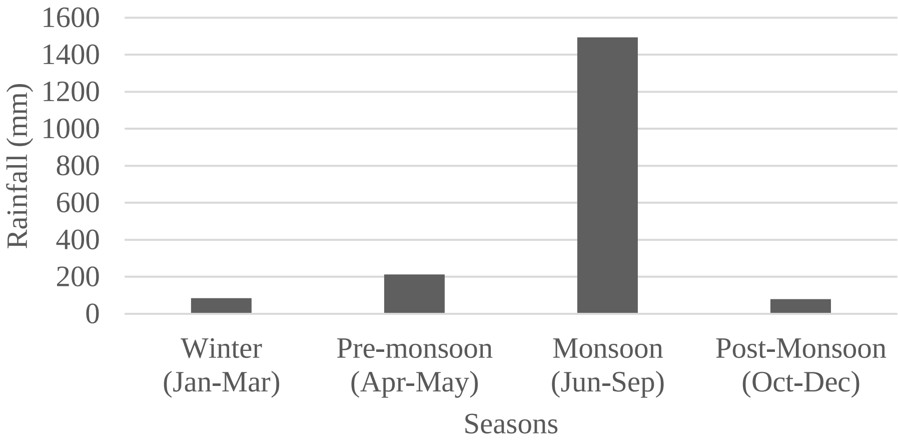

Figure 10: Seasonal Distribution of Rainfall for 1987-2015 in Garakot, Palpa

The figure below shows the yearly rainfall variability for 28 years (1987-2015). The years with highest variability were found to be 2014 and 1990, followed by 2005, 2006 and 2007. It means that these years saw a highly fluctuating precipitation trends among different months of the year. The year with the least variability was 1994, which means that the rainfall it received over the year was less fluctuating in comparison to other years.

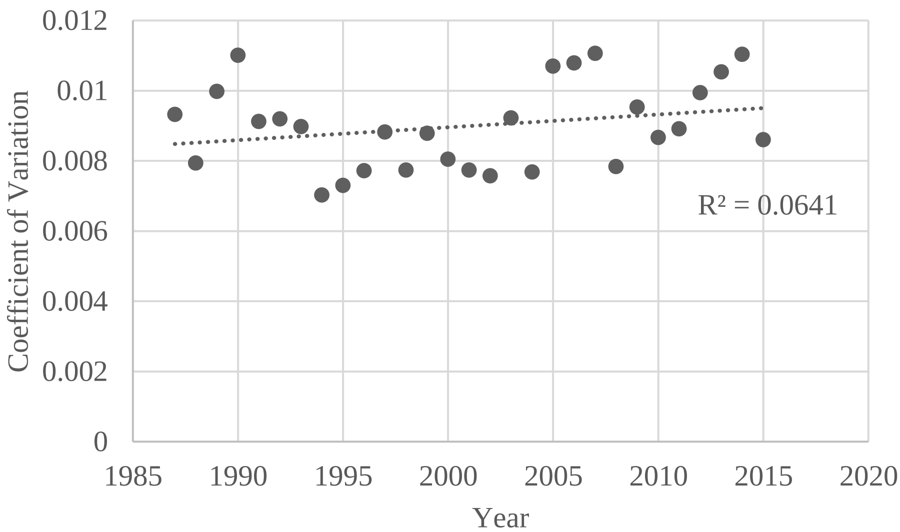

Figure 11: Yearly Rainfall Variability for 1987-2015 in Garakot, Palpa

Time series analysis of temperature of 27 years (1987-2014) from the station of Tansen, Palpa is shown in figures below. Figure 12 shows the trend of maximum temperature.

The highest and lowest values for yearly average of maximum temperatures were recorded in 2010 (27.83°C) and 1996 respectively (24.82°C). By performing a Mann-Kendall test on the time series data, it was found that the p-value is <0.0001. Therefore, it could be concluded that there is the trend in the series, with the value of Sen's slope 0.087. Which means that the rate of increase of maximum temperature is 0.087°C per year in the station of Tansen.

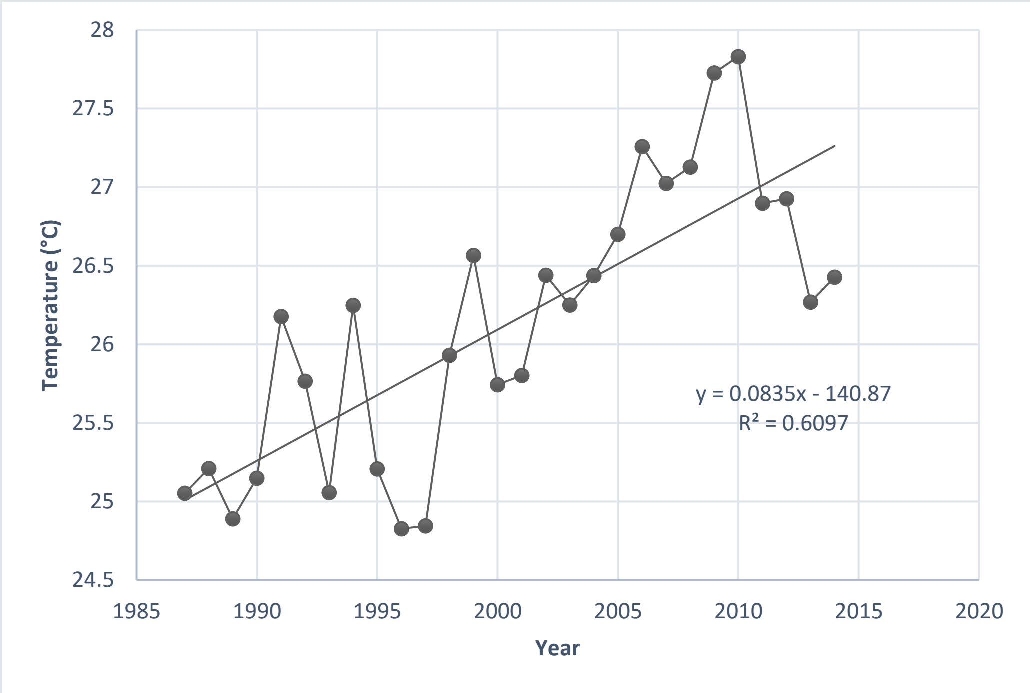

Figure 12: Yearly Average of Maximum Temperature in Tansen, Palpa

Similarly, the mean lowest temperature was recorded in 2010 (12.12°C) and the highest mean value of minimum temperature was recorded in 1988 (15.99°C). Mann-Kendall trend analysis showed that there is a trend in the series (p-value = 0.010 which is < α), with the value of Sen's slope -0.057, which means that the rate of decrease of minimum temperature is 0.057°C per year.

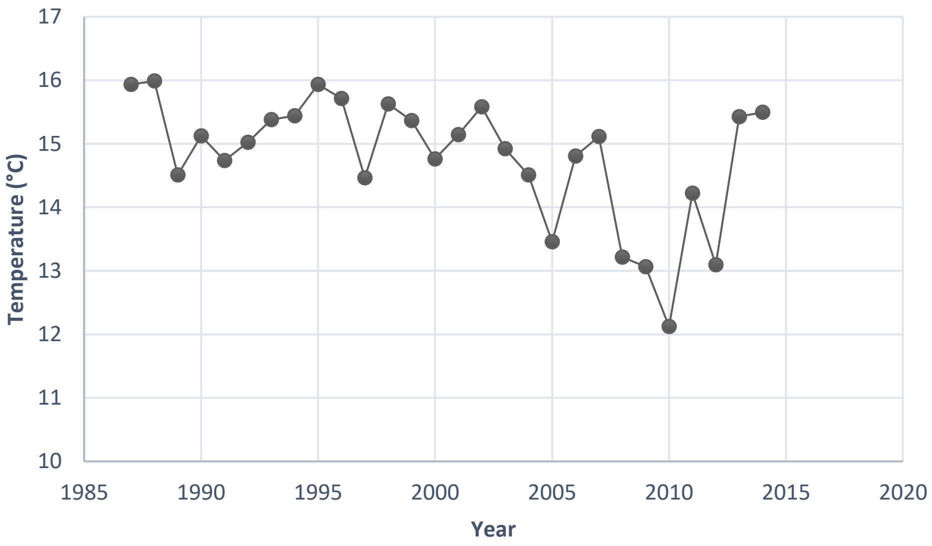

Figure 13: Yearly Average of Minimum Temperature in Tansen, Palpa

Likewise, trend analysis for yearly average was done for 27 years (1987 to 2014), which showed that the highest yearly average was recorded in 2007 (21.06°C) and the lowest was recorded in 1997 (19.66°C). Mann-Kendall test did not show a significant trend in the yearly average temperature, however, the value of Sen's slope was calculated as 0.011 which means that the yearly rate of temperature increase is 0.011°C.

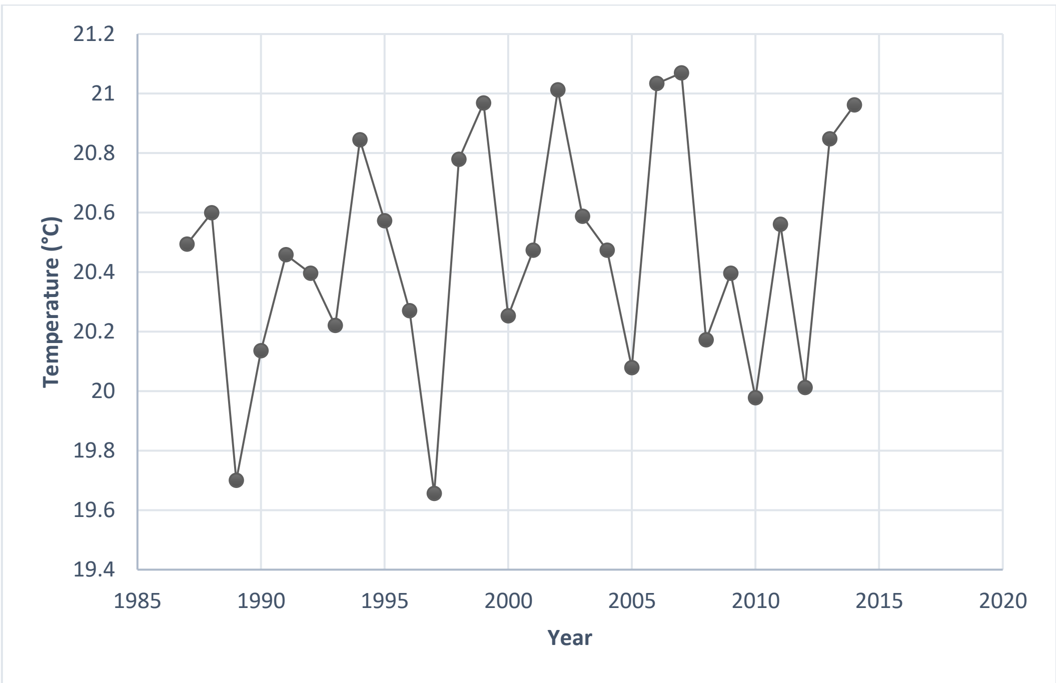

Figure 14: Yearly Average Temperature in Tansen, Palpa

4.2.2 Groundwater Recharge through Rainfall

Time series analysis of groundwater recharge through rainfall was done for 28 years (1987-2015) for the station of Garakot, Palpa. Empirical formula was used to calculate the recharge from yearly rainfall. The MK test gave a p-value of 0.075, which was found to be greater than the level of significance (0.05), therefore accepting the null hypothesis that there is no significant trend in the series. However, the value of Sen’s slope was found to be -1.66, indicating that there is a decrease in yearly groundwater recharge by 1.66mm/year.

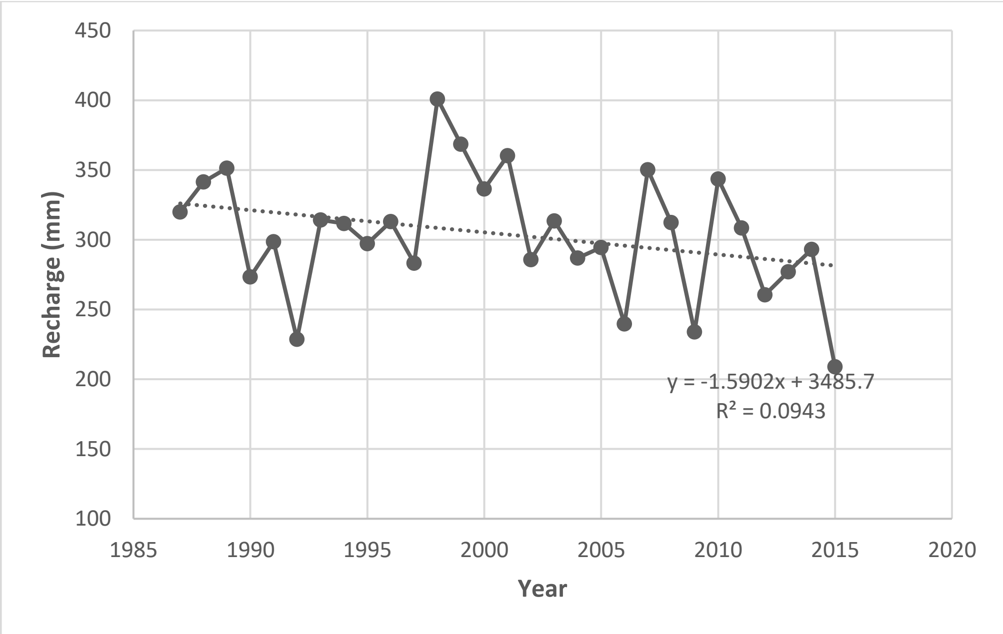

Figure 15: Annual Groundwater Recharge through Rainfall in Palpa

Seasonal recharge follows the same pattern as seasonal rainfall, chiefly because rainfall is the major source of groundwater recharge. The highest recharge is observed during monsoon, with its peak at the month of July, whereas the lowest recharge is observed during the post-monsoon season, with the trough at November.

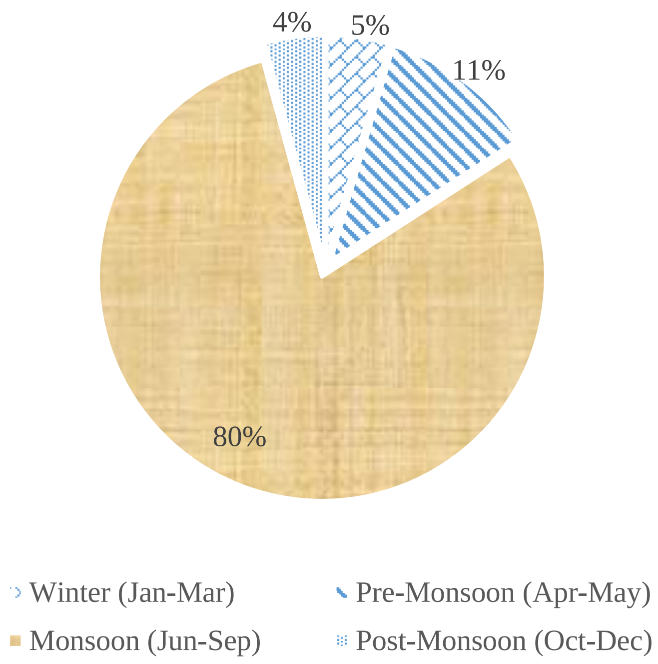

Figure 16: Seasonal Groundwater Recharge through Rainfall in Palpa

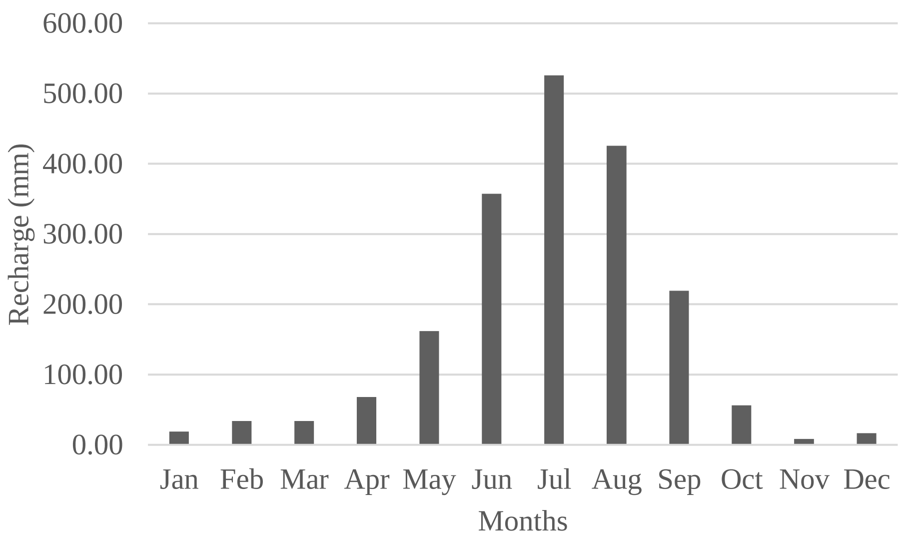

Figure 17: Average Monthly Recharge through Rainfall in Palpa

The value of recharge coefficients basically show the proportion of rainfall that infiltrates the ground and recharges groundwater system. The yearly pattern of recharge coefficients is very erratic, and does not follow a trend.

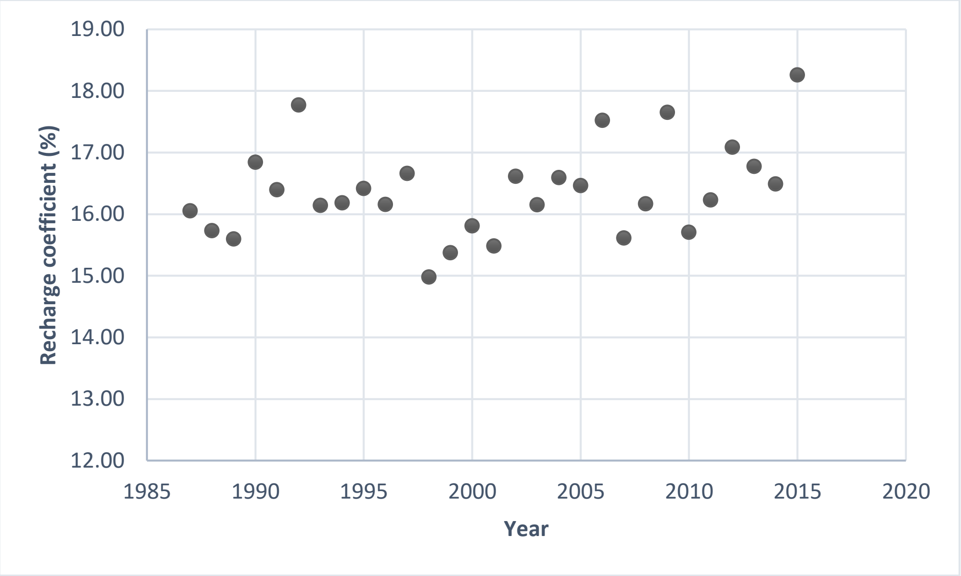

Figure 18: Recharge Coefficients for Tansen, Palpa

4.2.3 Perceptions of Climate Change:

Almost ninety percent of the respondents claimed that summer were becoming warmer than before, 10% perceived no change in temperature and 2% said the temperature had decreased over the years. On the other hand, 84% respondents claimed that winter was becoming colder, 8% didn't perceive any change and 7% thought the winter temperature had increased.

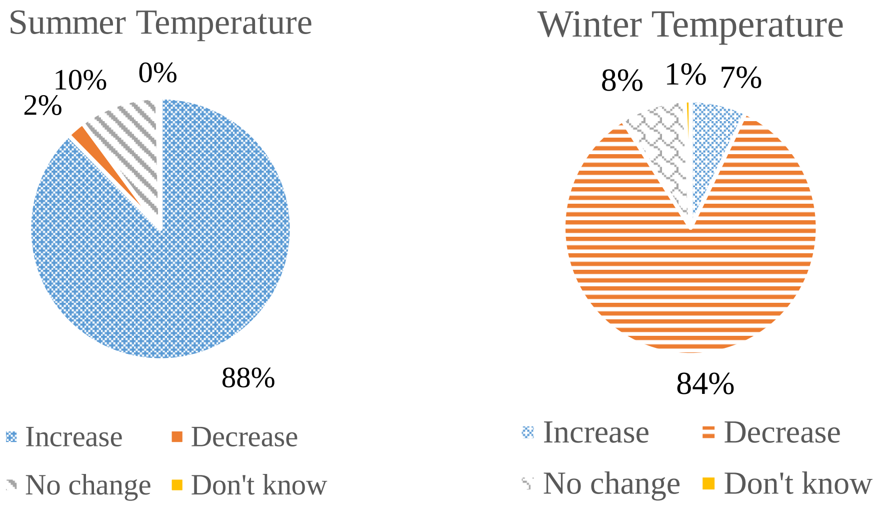

Figure 19: People's Perception of Summer and Winter Temperature

Sixty four percentage of the sample responded that they had observed a decrease in monsoon rain, 17% said there hadn't been any change and 7% claimed it had increased. 56% of the surveyed sample claimed that rainfall during the pre-monsoon seasons was decreasing over years.

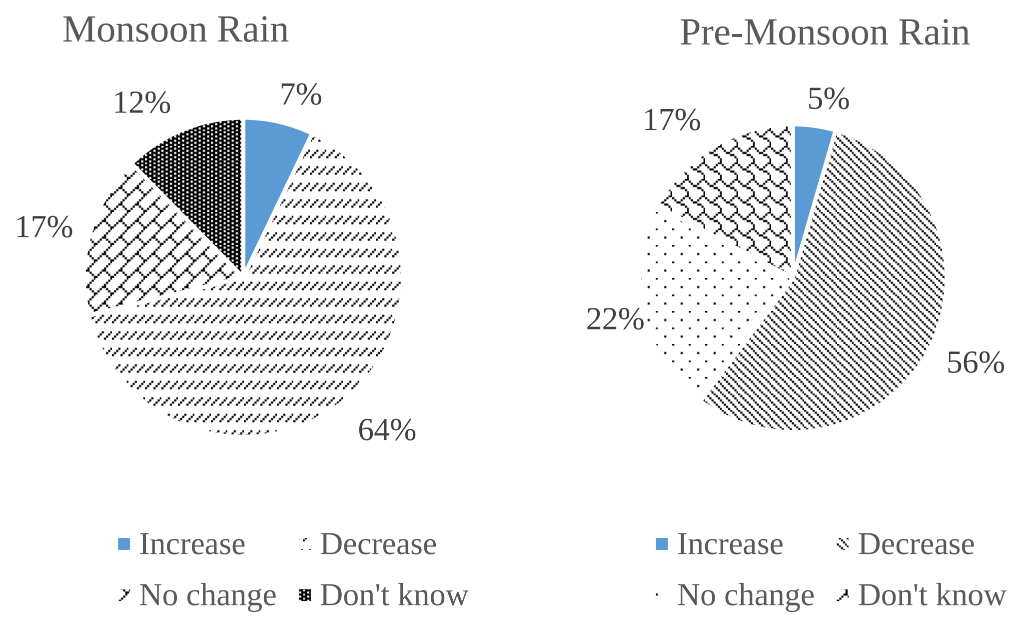

Figure 20: People's Perception of Rainfall

Accordingly, 90% of the respondents said that they had observed an increase in the rate of drying of springs (figure 21). A few people mentioned in the interview that "the town was growing in size, the stone paved pathways are now concretized, and as a result less water would infiltrate the grounds each year, hence the seasonal drying up of springs was taking place." Some respondents were found to be aware about the terminology of climate change, they had to say that "It could be the effects of climate change that in the near future, when the snow and ice will start melting rapidly with small increment in temperature, our mountains might no more be the source of water."

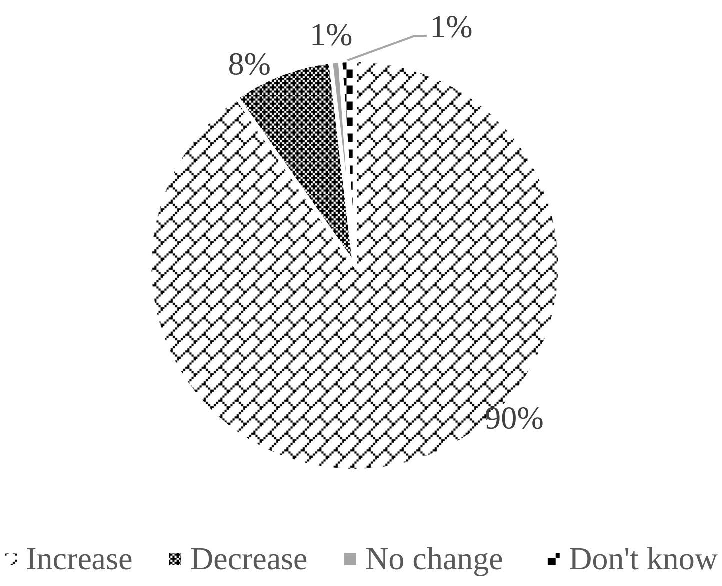

Figure 21: People's Perception of Spring Drying

4.2 Water Availability in Tansen, Palpa

4.2.1 Major Sources of Water

Figure 22 and 23 **s**how the classification of major sources of water used for drinking and other household purposes. For both purposes, water supplied from the municipal supply (User Committee) were used by all respondents. Besides that, the major alternative source of water was found to be water bought from tankers. Other sources such as springs and public taps were also used as per need and availability.

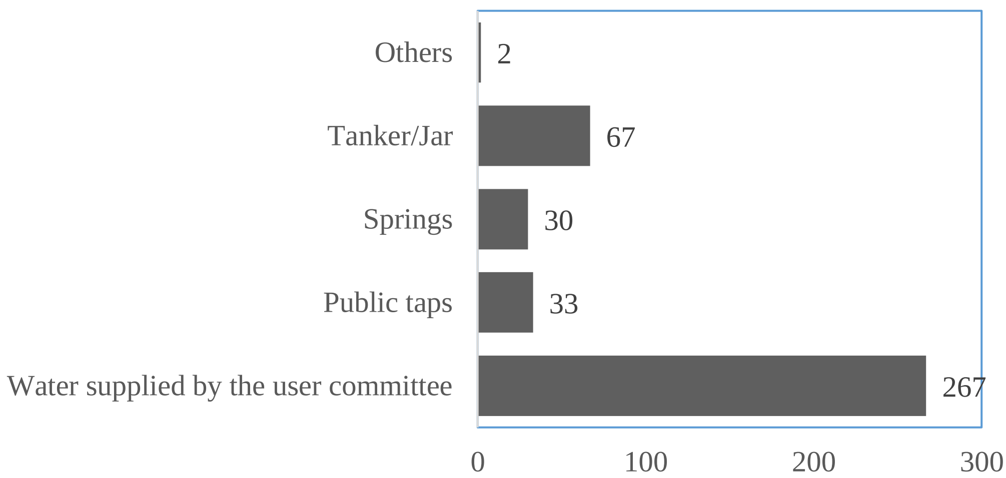

Figure 22: Sources of Drinking Water

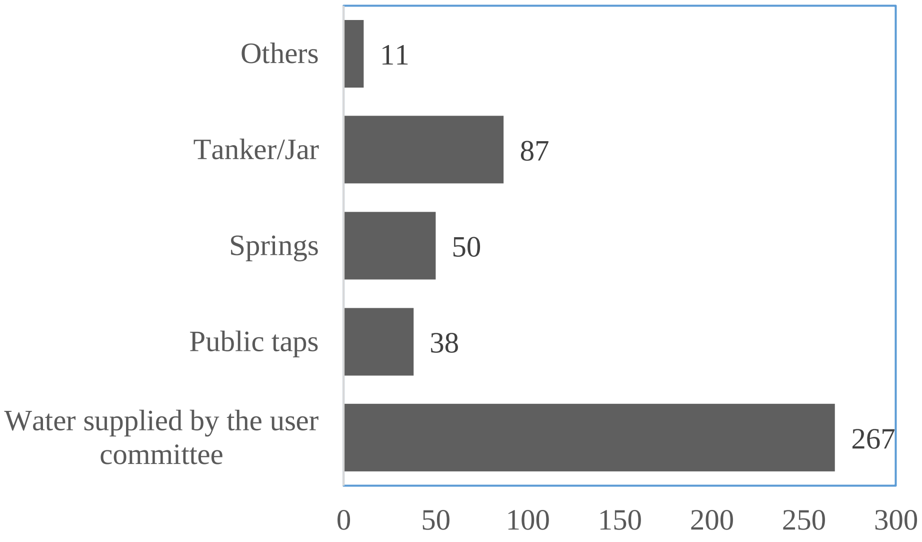

Figure 23: Sources of Water for Household Purposes

4.2.2 Source Map

There are five major groundwater sources tapped by the existing water supply project. These five sources (Banjha, Sisne, Bhulki, Teendhara and Holangdi) are larger than the other sources, therefore they are integrated into the municipal supply system. However, during dry seasons and pre-monsoon, there is considerable decrease in water in these sources as well. For the purpose of this study, 13 springs were identified. The remaining 8 springs besides the 5 major ones were chosen on the basis of number of people they serve as additional source of water, which has been identified through FGDs and KIIs. Almost all of these springs undergo seasonal decrease in supply. The location and status of these springs are given in table 5. Also identified are the point of storage or collection of water.

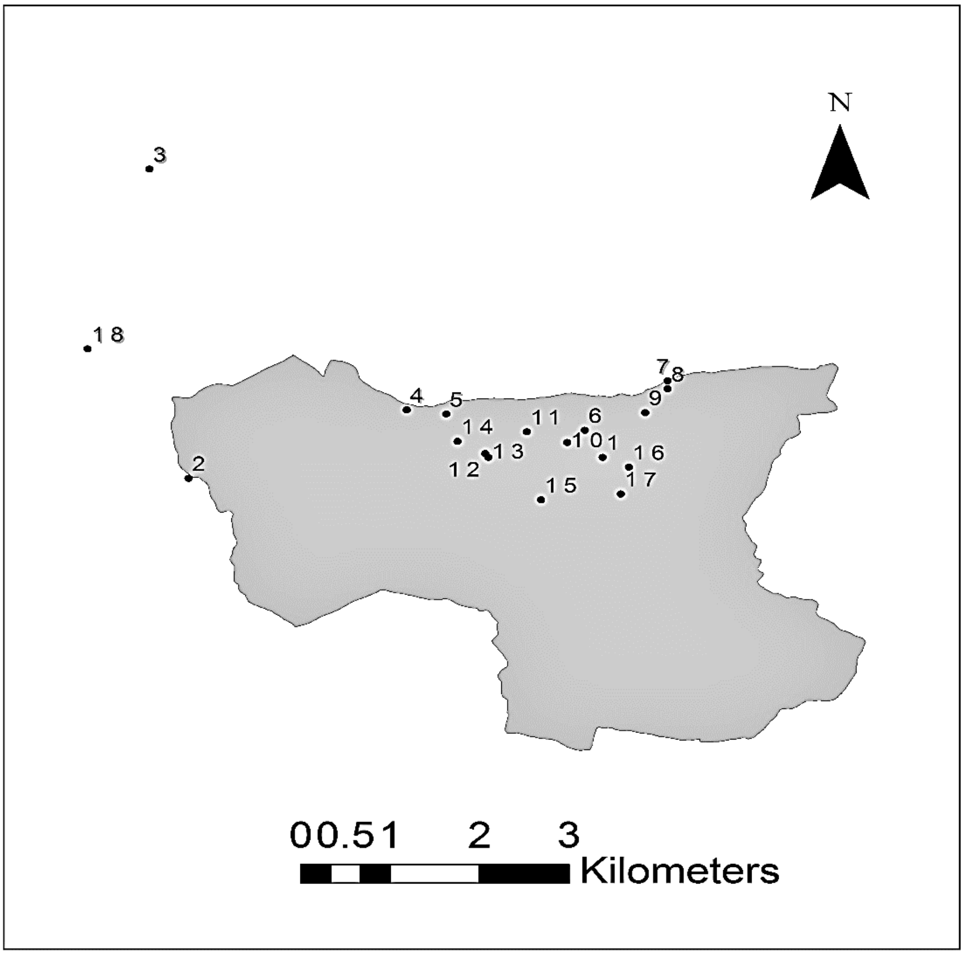

Figure 24: Map of major spring-water sources of Tansen, Palpa

Table 6: Location and Status of Spring-water Sources

S.N.	Name	X (Longitude)	Y (Latitude)	Status
1	Teendhara	83.551	27.865	Seasonal Decline
2	Sisne	83.509	27.863	Seasonal Decline
3	Bhulki	83.505	27.899	Seasonal Decline
4	Batase Storage	83.531	27.871	Functional
5	Batase Storage 2	83.535	27.870	Non-functional
6	Teendhara storage	83.549	27.868	Functional
7	Parihiti	83.557	27.874	Seasonal Decline
8	Dhondre (Kondrepani)	83.557	27.873	Almost Dry
9	Khalug Dhara	83.555	27.871	Seasonal Decline
10	Narayanthan	83.547	27.867	Seasonal Decline
11	Nisaandhara	83.543	27.868	Seasonal Decline
12	Holangdi	83.539	27.866	Seasonal Decline

13	Holangdi Storage	83.539	27.865	Functional
14	Sindure	83.536	27.867	Seasonal Decline
15	Kajipauwa	83.545	27.860	Seasonal Decline
16	Chhyangdi	83.553	27.864	Almost Dry
17	Chhyangdi Storage	83.553	27.861	Under-construction
18	Banjha	83.499	27.878	Almost Dry

4.3.3 Water Availability (Demand and supply)

The consumption of water by households is shown in figure 24 and is given as a range. The largest number of respondents consume less than 250 liters of water per day per household (64%), followed by 250-500 liters (20%). Only 16% of the respondents consume more than 500 liters of water each day, among which 4% consume more than 1000 liters of water each day. However, the demand for water is much larger. The water supplied by the user committee is not enough for most respondents. 52.8% of the respondents said that their daily water demand is 500-1000 liters, followed by 29.2% with a demand of 1000-15000 liters. Only 5.24% have a daily water demand of less than 500 liters.

Assuming that the consumption of water is equivalent to the water supply, total supply for 2800 households under the User Committee was calculated to be 840,000 liters per day (Table 7). Similarly, demand of water for 2800 households was calculated to be 2,926,000 liters per day. This result was found to be consistent with the figure of demand and supply provided by the User Committee (Table 9). Water demand and supply for a household was calculated to be 300 liters and 1045 liters respectively. Whereas per capita water supply and demand was calculated to be 81.3 liters and 283.19 liters respectively. The demand-supply ratio was calculated to be 3.48 which was found to be similar with the figure provided by the User Committee (3.53).

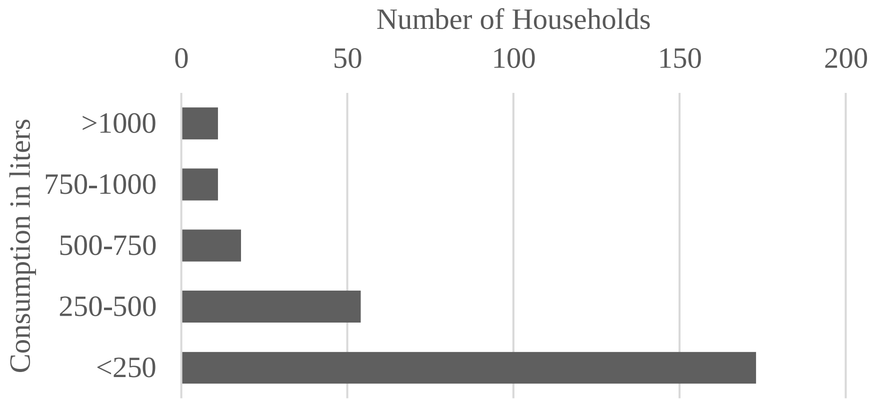

Figure 25: Daily Water Consumption by Households

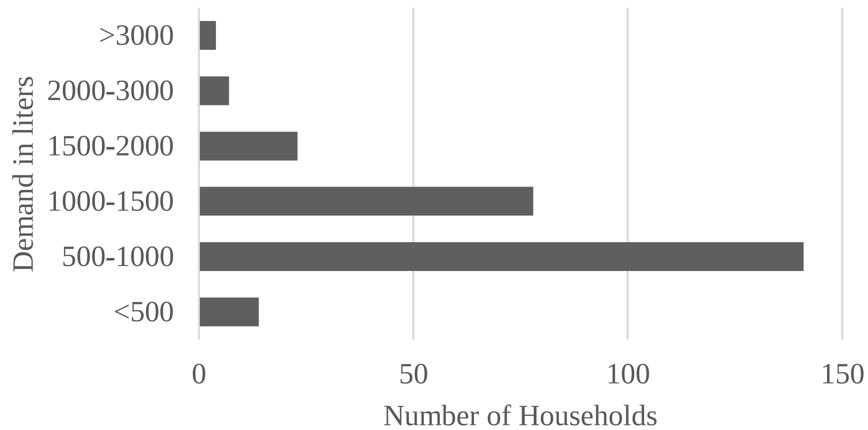

Figure 26: Daily Water Demand by Households

Table 7: Total Daily Water Supply Estimation

Supply Range (liters)	Average Supply (liters)	No. of HHs	Supply for Sample Size (liters)
>1000	1100	11	12100
750-1000	875	11	9625
500-750	625	18	11250
250-500	375	54	20250
<250	150	173	26250
Total		267	79475

Average Household Supply = 79475 liters/267 = 297.66 liters

Round-off value of average household supply = 300 liters

Therefore, supply for 2800 households = Average HH supply × No. of HHs = 840,000 liters

Average Household size for Tansen municipality = 3.69 (CBS, 2011)

Per capita supply = Average HH supply/Average HH size = 300 liters/3.69

Therefore, per capita water supply = 81.3 liters

Table 8: Total Daily Water Demand Estimation

Demand Range (liters)	Average Demand (liters)	No. of HHs	Demand for sample size (liters)
<500	350	14	4900
500-1000	750	141	105750
1000-1500	1250	78	97500
1500-2000	1750	23	40250
2000-3000	2500	7	17500
>3000	3200	4	12800
Total		267	278700

Average Household Demand = 278,700 liters/267 = 1043.82 liters

Round-off value of average household Demand = 1045 liters

Therefore, demand for 2800 households = Average HH demand × No. of HHs = 2,926,000 liters

Average Household size for Tansen municipality = 3.69 (CBS, 2011)

Per capita demand = Average HH demand/Average HH size = 1045 liters/3.69

Therefore, per capita water demand = 283.19 liters

Table 9: Comparison of Demand-Supply Ratio

	Calculated (liters)	Provided by the UC (liters)
Supply	840,000	850,000
Demand	2,926,000	3,000,000
Demand-Supply Ratio	3.48	3.53

Majority of respondents pay less than NPR 500 each month for water supply to the User Committee (figure 27). The billing is done by using a meter to measure the consumed water each month. Very small proportion of respondents pay more than NPR 1000 per month to the User Committee for water supply. Regarding the total monthly expenditure on water, the minimum expenditure amount was found to be NPR 100 and the maximum was found to be NPR 1950 (figure 28). The box-plot of monthly expenditure is skewed to the left, with the median value of NPR 280 and the first and third quartile values NPR 215 and NPR 450 respectively.

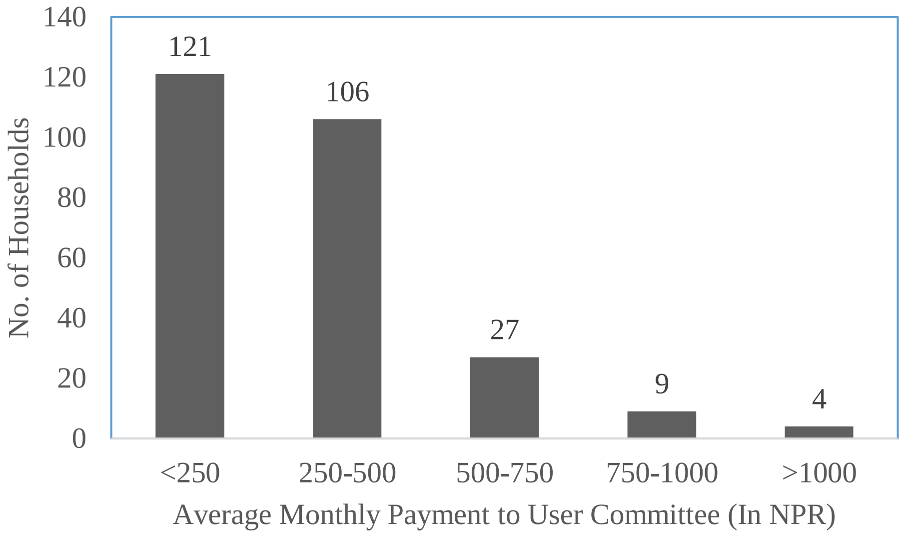

Figure 27: Monthly Payment to User Committee by Respondents

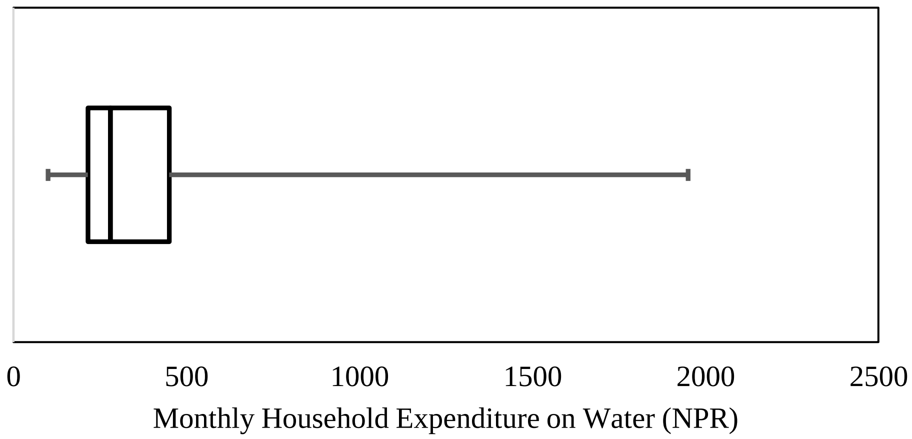

Figure 28: Box Plot of Monthly Household Expenditure on Water

The duration of water supplied each day varied among respondents. Although a majority of respondents (82%) claimed to receive water for 45 minutes to 1 hour each day, about 13% said that they get water for less than 45 minutes, whereas 5% responded that they get water for more than 1 hour.

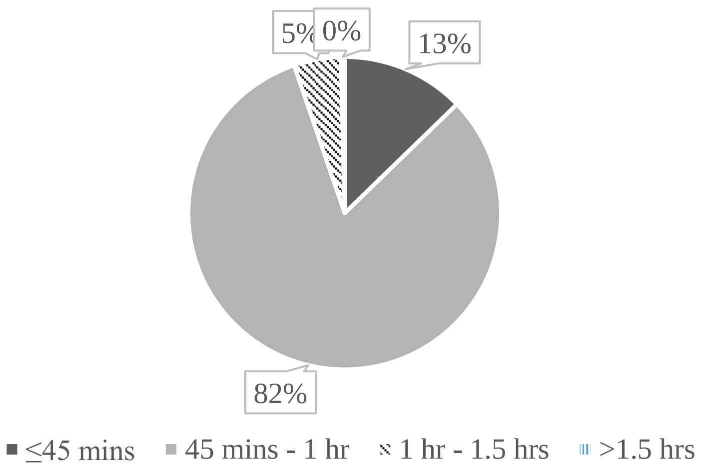

Figure 29: Average Duration of Water Supply

4.5 Underlying Governance and Management

4.5.1 Institutional Structure

The User Committee is a community-managed body not under the control of government. The administrative and financial activities are the responsibility of the committee itself, although technical and infrastructure support is provided by the government. According to the KII and FGDs conducted, the water supply project was handed over to the User Committee in 2010 after run by the DWSS (Department of Water Supply and Sewerage) – District Division Office. DWSS functions under the Government of Nepal’s Ministry of Water Supply and Sanitation. Its district division office is responsible for providing technical and infrastructure support for the implementation of policies. While smaller infrastructure works are carried out by the User Committee itself, larger projects and construction activities are carried out by DWSS as a support. Regional Director is responsible for the monitoring of activities, whereas the local User Committee is advised by the current Chief District Officer (CDO), Municipal Chief and the district chairman of FNCCI (Federation of Nepalese Chambers and Commerce Industry).

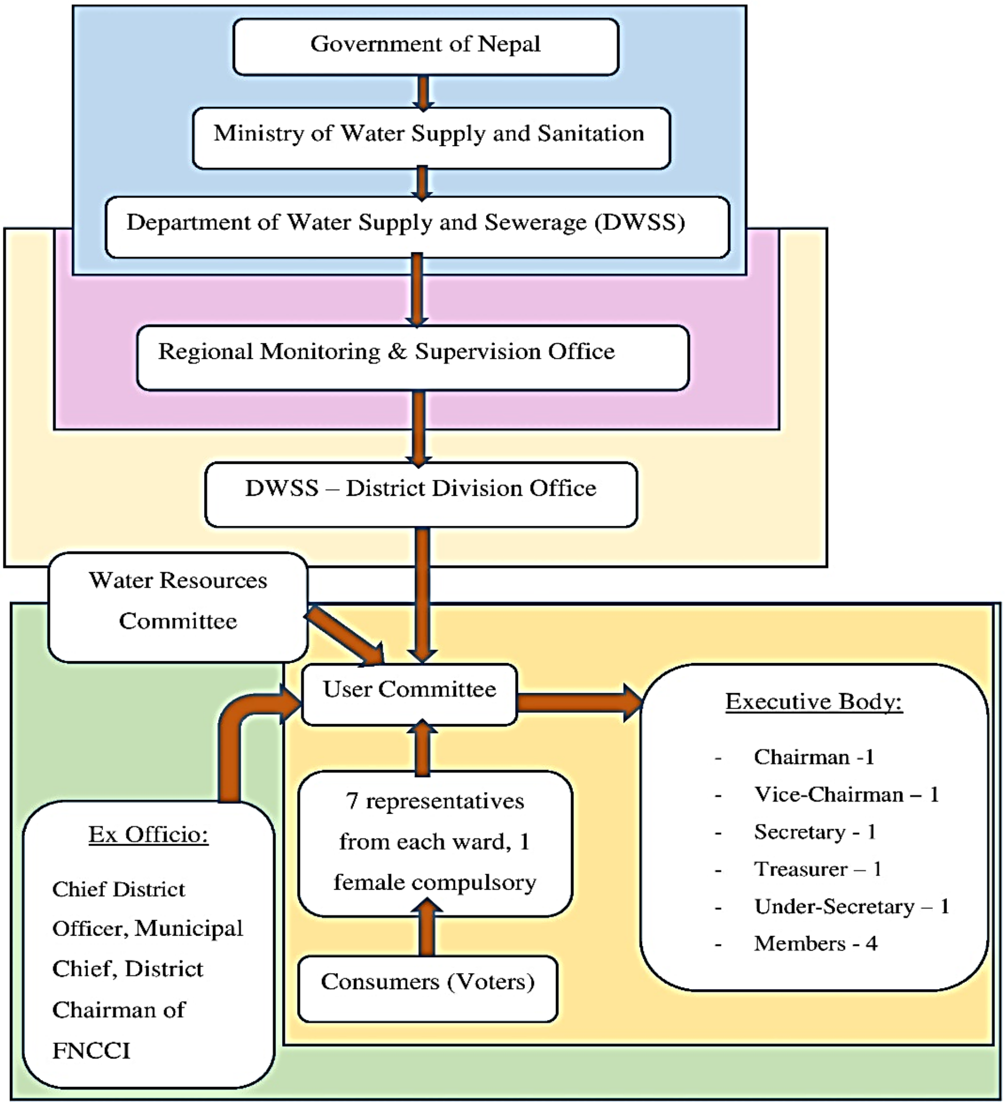

Figure 30: Institutional Framework of TDWUC

Table 10: Major Roles of Various Components in Institutional Framework

Color	Major Role
	Policy Making, Cross sectoral coordination and International Cooperation
	Monitoring, Infrastructure Support
	Infrastructure, Technical Support, Support in Implementation of Policies
	Advisory Body
	Tansen Drinking Water User Committee

4.5.1.1 Issues of the User Committee

Various factors play a role in the supply of water. Based on the Focus Group Discussions and Key Informant Interviews, major issues of the Tansen Drinking Water User Committee have been identified.

Table 11: Priority Ranking of the Issues of User Committee as Identified by FGDs and KIIs

S.No.	Issues of the User Committee
1	Drying of sources
2	Old water supply system, Lack of maintenance and repair
3	Pricing
4	Issues in management and distribution
5	Lack of technical capacity
6	Insufficient storage system
7	Lack of ways to store free-flowing water from smaller springs and stone-spouts
8	Unclear communication of roles
9	Activities and financial system of TDWUC not transparent
10	Unequal distribution of water in all parts of town
11	Inadequate measures of source conservation
12	Power outage (Electricity issues)
13	Leakage of water

4.5.2 Governance

The proportion of male who have participated in the General Assembly meetings and activities of the User Committee was found to be higher (26%) as compared to female (13%) (Figure 31). Male respondents were also found to be more aware about the issues of the User Committee. χ^2 test of Independence was performed on the two variables: participation and awareness. With a p-value of 0.012 (which is less than level of significance, 0.05), the null hypothesis was rejected accepting the alternative hypothesis, which showed that the two variables are not independent.

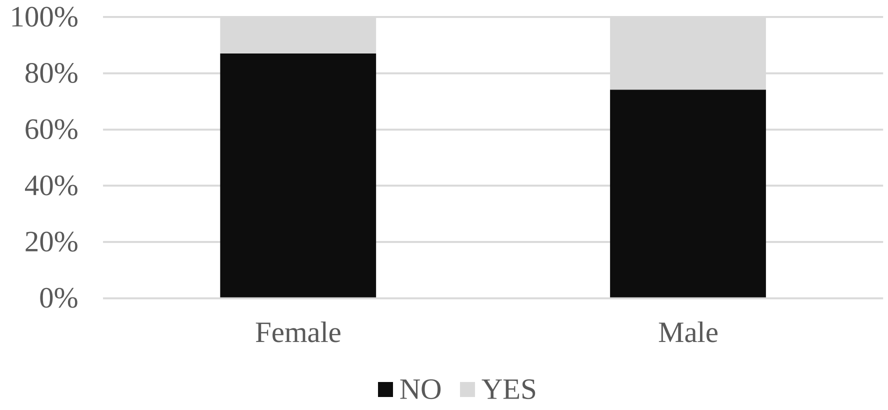

Figure 31: Gender-wise Participation in the User Committee Activities

For the similar analysis of χ^2 test of Independence between participation and caste, p-value was found to be 0.691 with 95% confidence interval, which is greater than the level of significance, hence accepting the null hypothesis that there is no association between those two variables. The highest proportion of caste that had participated in the General Assembly or other activities by the User Committees were found to be Brahmins (24%), followed by Newars (23%). 19% of Chhetri and Dalits both had attended the General Assembly (figure 32).

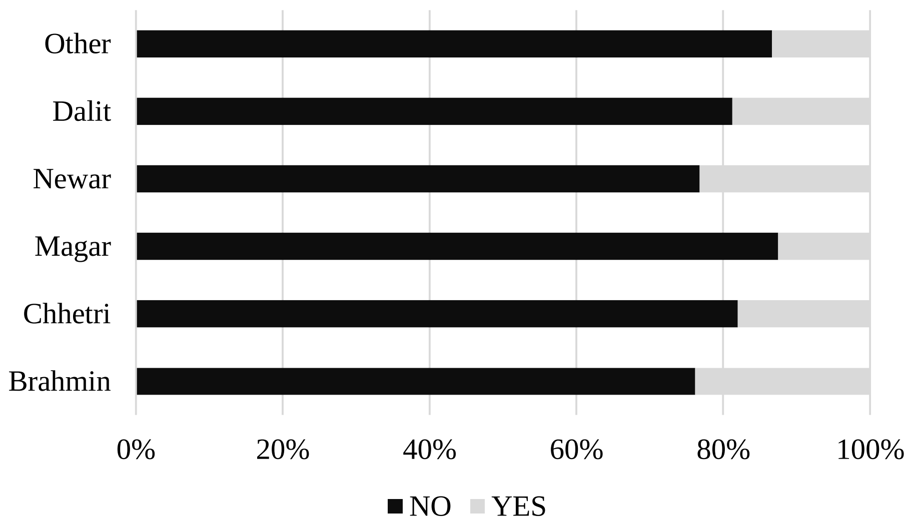

Figure 32: Caste-wise participation in the User Committee Activities

Likewise, Brahmins were the caste who were most aware about the User Committee issues (32%), followed by Chhetri and Newars (25% and 24%) respectively (figure 33). Low awareness was found to be in Magar and Dalits. χ^2 test was performed between Awareness and Caste which showed that with a p-value less than 0.0001, the null hypothesis was rejected, confirming that there is a significant association between the two variables. Accordingly, χ^2 Test showed that gender and awareness are independent of each other, with a p-value of 0.539 with 95% confidence. 25% of the male were aware about the issues as compared to 20% of the females (figure 33). Likewise, 45% of the male respondents reported to have been involved in the User Committee by providing suggestions whereas only 31% females reported to have done so.

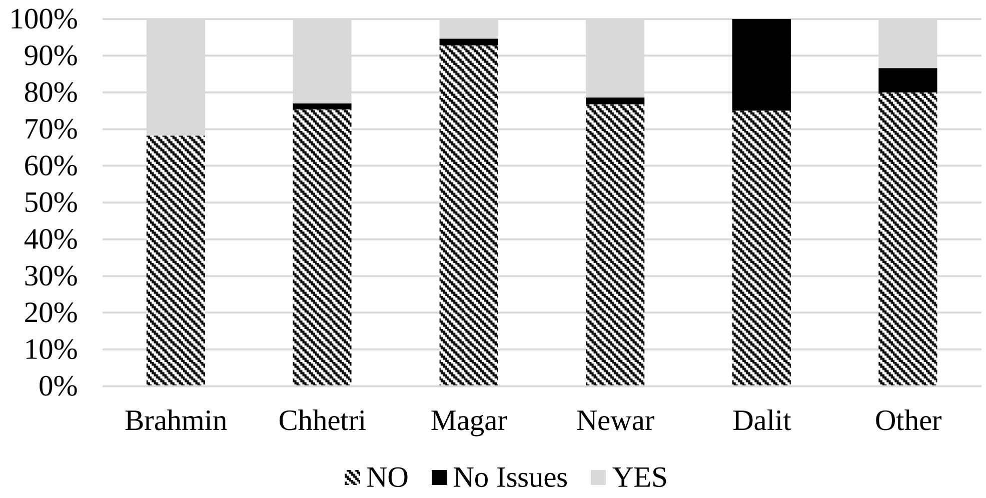

Figure 33: Caste based awareness about the Issues of User Committee

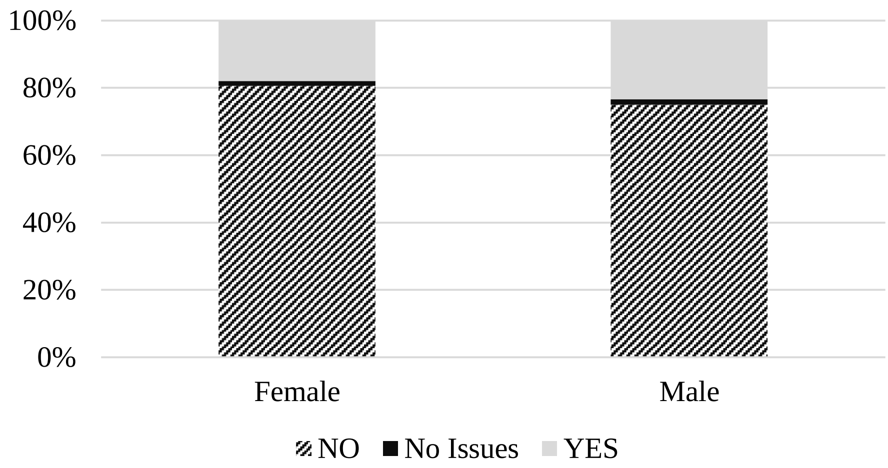

Figure 34: Gender based awareness about the Issues of User Committee

Forty three percentage of Brahmins had been actively involved in providing suggestions whereas 36% Chhetris, 25% Magars, 41% Newars and 31% Dalits had done so (figure 35). Likewise, getting involved in the affairs of User Committee was found to be independent of the caste of respondents. With the p-value of 0.2961 at 95% confidence interval, the null hypothesis that there is association between the two variables was rejected. Similar results were found for gender. χ^2 test performed on gender and involvement showed that, with p-value of 0.016 (less than level of significance, 0.05), the null hypothesis was rejected. Hence confirming that being involved by providing suggestions is dependent of gender as well.

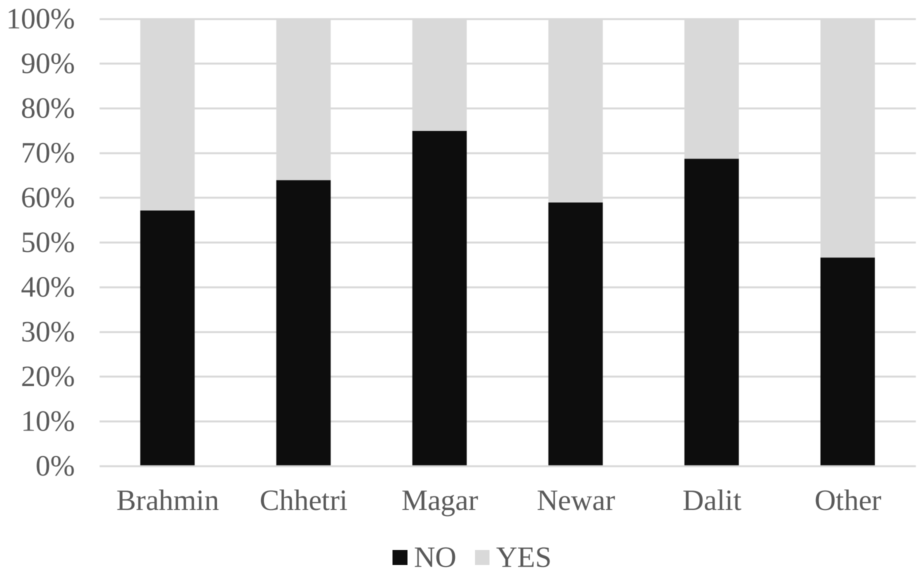

Figure 35: Caste based involvement (Providing Suggestions) in User Committee

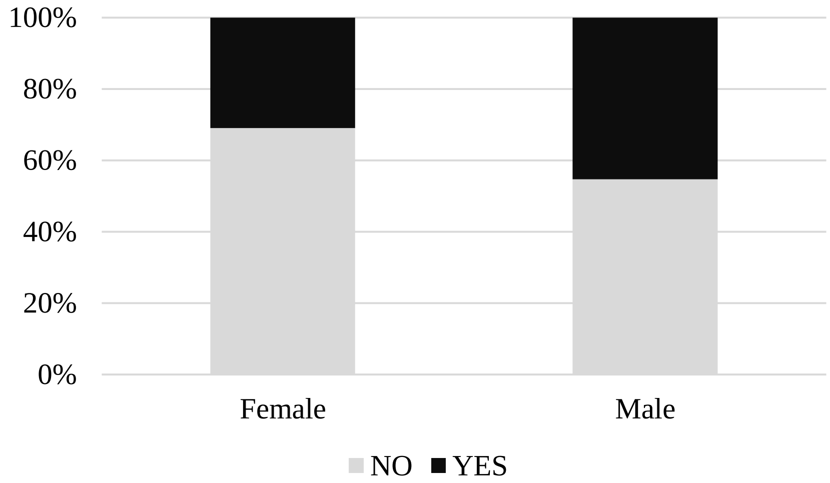

Figure 36: Gender-based involvement (Providing Suggestions) in User Committee

A similar test on caste and transparency showed that there is no association between the two variables. With p-value of 0.148 and level of significance 5% for 95% confidence interval, the null hypothesis is accepted which states that the variables are independent of each other. Likewise, between gender and transparency as well, no significant association was found (p-value = 0.19, confidence interval = 95%). However, it can be noticed that a large proportion of total respondents are clueless about transparency.

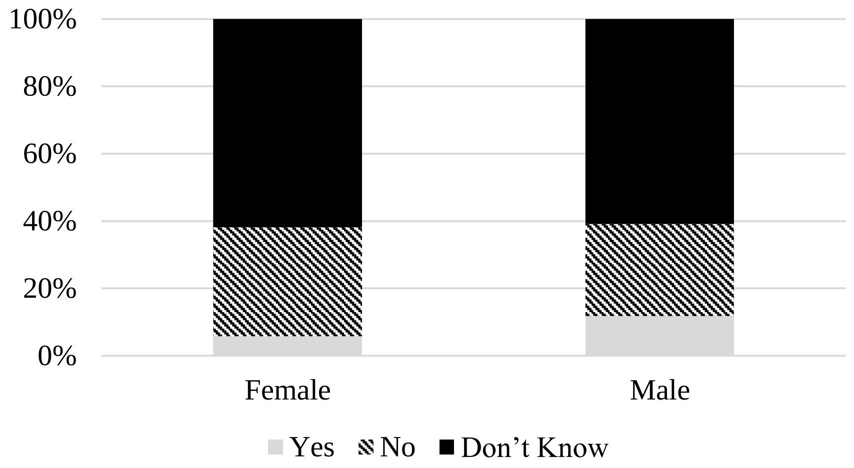

Figure 37: Gender based perception of transparency

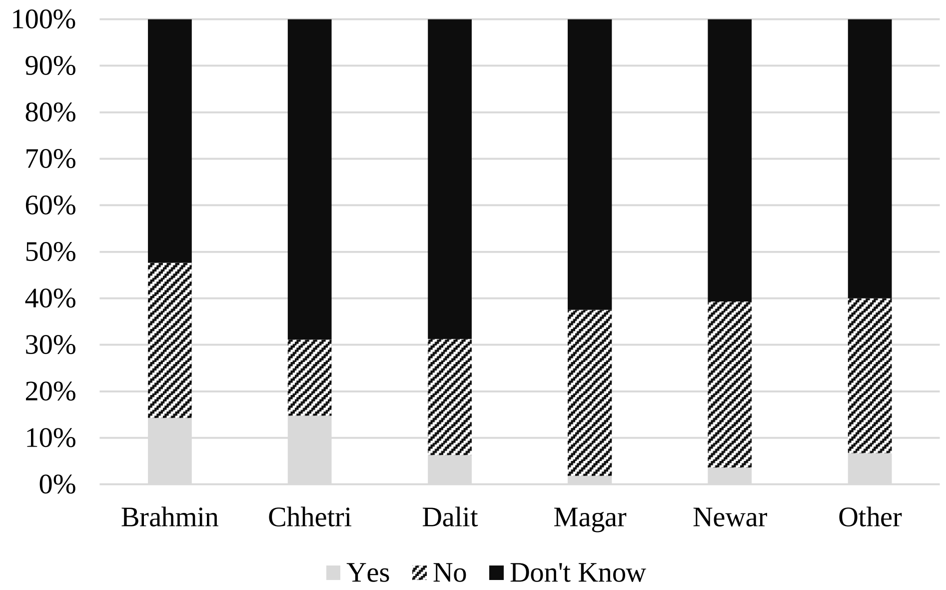

Figure 38: Caste based perception of transparency

A test of χ^2 association between two variables: Attendance in the yearly general assembly and Perception about the accountability of the User Committee resulted that there is an association between two variables. The null hypothesis was set that there is an association between two variables against the alternative hypothesis which stated that there is no association. Since the observed χ^2 value (19.383) was found to be greater than χ^2 tabulated value for 2 degree of freedom and 0.05 level of significance, and the p-value was <0.0001 (which is less than α), the null hypothesis was accepted. Which means that, higher the number of people who attended the yearly General Assembly, more likely they are to have positive perception about the User Committee.

Table 12: Association between Participation and Perception about the Accountability of User Committee

Attendance in the yearly General Assembly	Perception About the Accountability of the User Committee		
	Responsive	Non-Responsive	Don’t Know
YES	14	37	0
NO	15	192	9

4.5.3 Water Governance Indicators

Indicators of water governance given by OECD (OECD, 2015) has been used to assess the status of governance. The indicators have been classified into 3 broad categories: Efficiency, Trust and Engagement and Effectiveness. Each of them contain sub-indices, which have been assessed in the table below.

Table 13: Status of Water Governance Indicators

Indicators	**Status**
EFFICIENCY	
Data and Information	Requirements for cost-effective and sustainable methods for sharing water is defined and communicated Status of water resources is not defined Institutional mapping is done Water information system not applied
Financing	Government support in the initial years to cover the losses incurred

Indicators	Status
	Strategic financial planning is done by User Committee and DWSS-Division Office, although implementation is poor Budgeting system not completely transparent
Regulatory Frameworks	Coherent institutional framework integrating both bottom-up and top-down approach Rules and processes are transparent, non-discriminative and participatory Poor co-ordination and conveying of rules, regulations and processes Enforcement procedures and incentives not clear
Innovative Governance	No pilot-testing of innovative governance No social learning facilitation Co-operation and capacity building facilitated by DWSS Science-policy interface non-existent in ground-level
TRUST AND ENGAGEMENT	
Integrity and Transparency	Consumers' perception of transparency is low Integrity and transparency encouraged in National Policies No clear accountability and control mechanism for transparent water policy implementation
Stakeholder Engagement	Identification of actors in public, private and non-profit sector Under-privileged groups are given subsidy Line of decision making well-defined Encouraged engagement of actors at different sectors
Trade-offs Across Users and Areas	Decision making processes affected by political agenda Participation in decision-making from vulnerable groups and across different sectors is poor Lack of evidence-based assessment of the consequences of water-related policies on local level
Monitoring and Evaluation	Establishment of Regional Monitoring and Supervision Office under Regional Director Gap between policy and implementation level bridged by sharing of timely evaluation results

Indicators	Status
	Results of monitoring and evaluation poorly communicated
EFFECTIVENESS	
Clear Roles and Responsibilities	Specific roles and responsibilities across the institution Role of operational management and service delivery to the UC Overlaps and conflict of interest identified
Policy Coherence	Inter-departmental policy coherence mechanism facilitated and encouraged for integration of various sector affecting water Absence of effective and integrated central planning organization in water sector Identification and addressing to the policy barriers beyond water sector is not done properly
Capacity	Technical and financial capacity is supported by the government Limited institutional and technical capacity of the User Committee Lack of technical professionals in local level to ensure the quality of water supply

CHAPTER 5: DISCUSSION

5.1 Climate Change and Groundwater Recharge

5.1.1 Climate Change and its Perceptions

Rainfall data analysis indicates that the rainfall is decreasing each year in Palpa at the rate of 13.58mm/year. Average yearly rainfall was found to be 1870mm, whereas the average yearly precipitation of Nepal is 1500mm (OECD, 2003). However, no statistically significant trend of decrease was found in the yearly rainfall trend of Palpa. Number of rainfall days each year showed a decreasing trend. The highest rainfall days was observed in 2002 and the lowest rainfall days was observed in 2012. Projection of annual precipitation does not show a significant trend by 2090 (NCVST, 2009). And although no particular change has been observed in the amount of seasonal monsoon rainfall, a decrease in the total number of rainy days has been noted (APN, 2007). Similar study done by Shrestha et al. (2000) for the analysis of precipitation records from 78 stations from 1948 to 1994 showed no distinct long-term trends in precipitation despite showing some annual and decadal variability. While comparing this with people's perception, the proportion of respondents who noticed a decrease in rainfall wasn't as noteworthy as those who noticed temperature change. 64% respondents claimed to have witnessed a decrease in monsoon rain and 56% responded that they have observed a decline in pre-monsoon rain.

The month of July observes the highest rainfall in Palpa, which is the peak of monsoon season whereas November receives the lowest amount of rainfall. Pre-monsoon and winter seasons observe the lowest amount of rainfall. Study done in 166 stations of Nepal with rainfall data from 1976 to 2005 showed that 80% of the total annual rainfall occurs during the monsoon season, while the months receiving highest and lowest rainfall are July and November respectively (PAN, 2009). The year 1997 was found to have received most rainfall. Whereas 1992 received the least rainfall. This was found to be comparable with Shrestha et al. (2000) which termed 1992 as an exceptionally dry year, which coincides with the El-Nino of 1992-93. A strong correlation was showed by El-Nino Southern Oscillation (ENSO) and precipitation in Nepal (Shrestha et al, 2000).

Analysis of temperature data showed that there is a significant trend in the increase of maximum temperature. Temperature is shown to be increasing at the rate of 0.087°C per year. Similarly, the analysis of yearly average of minimum temperature showed that there is a significant trend in the decrease of minimum temperature, with a rate of 0.057°C per year. When the results of climate trend analysis were compared with people's perception, it could be observed that 88% respondents had noticed the increase in temperature in summer and 84% respondents observed a decrease in winter temperature. The warmest and coldest years were found to be 2007 and 1997 respectively. This trend was found to be similar to the study of Shrestha et al. (1999) which established the rate of temperature increase in 49 stations of Nepal from 1977 to 1994 to be 0.06°C per year. The average maximum temperature reached a peak at 2010 and 2009, which was found to be consistent with DHM (2009) which has stated 2009 as an extreme in terms of temperature records.

The rate of drying of springs was noticed by 90% of respondents. In a study done by Poudel & Duex (2017), local farmers of Nuwakot, Nepal identified spring drying as one of the major impacts of climate change. Severe decline in the flow of water was reported by the study, combined with decline in perennial water sources and downhill migration of water sources. The study showed that 73.2% of the spring sources had undergone decline and 12.2% had dried up over the past 10 years (Poudel & Duex, 2017).

5.1.2 Groundwater Recharge through Rainfall

No statistically significant trend was observed in annual groundwater recharge, but the rate of decrease was found to be 1.66mm/year. The seasonal recharge rate showed that the highest amount of groundwater recharge through rainfall occurs during monsoon season, which is also the season that experiences highest rainfall. The lowest recharge rate is observed during the winter season, which is also the season for lowest rainfall. The recharge coefficients are found to be erratic, ranging from 14.98 to 18.26. This means that about 14.98 to 18.26% of the total rainfall infiltrates the ground and recharges groundwater. Although the trend in decrease of recharge rate is low, increasing temperature could lead to an increase in evaporation and hence reduced water available for recharge. Also, considering that the groundwater recharge doesn't change much, the increase in extraction to meet increasing water demands for various purposes (UNESCO, 2004; Taylor et al., 2012) like irrigation, industrial, municipal uses could cause a decline in groundwater.

Various studies have come up with similar conclusions. For the most parts of world, groundwater recharge could increase by 2050 under the influence of climate change, given that the recharge capacity increases as well (Doll & Florke, 2005; Jykarma & Sykes, 2007). However, the infiltration capacity is limited, so the rate of infiltration is predicted to be lower than runoff. Also, in arid and semi-arid areas, groundwater recharge is expected to decrease intensely (Doll & Florke, 2005). Also, precipitation is expected to be more intense and frequent, surface runoff will increase as well. Evapotranspiration rates will be higher because of warmer environment (Jyrkama & Sykes, 2007). Although it is unlikely for most densely populated areas of the world, the groundwater would decrease more than 10% by 2050. However, the vulnerability of affected population depends not only on the amount of decrease in groundwater availability, but also on the sensitivity of the population living in that area (Doll, 2009). For example, in the United States, the recharge rate is expected to decline 10-20% in the Southern aquifers, slight increase in the Northern aquifer and decrease in the mountain areas because of decline in snowpack (Meixner et al., 2016). The groundwater volume, ultimately, not only depends on the recharge rate but also on the extraction rate which is dependent on the demand for water.

Groundwater potential of mid-hills of Nepal has not been estimated systematically. Few studies suggested that it has been found to be lower than that of Terai region. The water from aquifers in mid-hills discharges through fractures and springs, and form an important part of lifecycle of the mid-hills. The basement of aquifers in mid-hills is crystalline and has low permeability, who tends to encourage run-off and discourage recharge (Bricker et al., 2014).

5.2 Water Availability in Palpa

5.2.2 Source Mapping

There are five major spring-water sources integrated into the water supply system of TDWUC. Besides these five sources, numerous springs and sprouts are used for water retrieval on a regular basis. However, the first tapped spring, Banjha has immensely decreased its supply. The other four springs are the life-line of the emerging town. The water from Sisne and Bhulki have to be pumped up to town in stages. Water from Bhulki is pumped in 4 stages whereas Sisne in 3 stages. The cost of pumping (electrical and mechanical cost) is very high. Any interruption in power leads to the town devoid of its water supply, which is a frequent event during the dry season where thunderstorms are common which lead to power-cut.

Bhulki, Sisne and Banjha lie outside of the realm of Tansen Municipality. Currently, the water from Banjha is only supplied to nearby localities. Whereas Bhulki and Sisne are the major water sources for Tansen. TDWUC gives price subsidy to the locals of those areas because of their poor economic conditions. Besides the sources listed here, there have been made several attempts to extract water from underground to add to the existing system. Several protests have been faced by TDWUC by the locals of the possible extraction areas for ownership and sharing of resources, as a result of which, the projects had to be cancelled before they could be implemented.

According to the public, the alternative springwater sources have ample amount of water flowing through them, but because of lack of source protection and maintenance, a lot of water goes to waste. For example, the water which is not used during the night time could be collected and stored. Stored water from all the alternative sources could add up for a large amount of water supply. Also, it has been identified during the FGDs and KIIs that a major issue of water management is its pricing. When the water supply was handed over to the user committee, the cost of water was extremely low since government was bearing all the costs. But it was difficult for the committee to operate under financial loss. However, significant increase in price suddenly was not an option, the consumers would not approve of it. As a result of which, the committee faced financial loss for almost 6 years before hiking the price of water in 2017 February. This limited the capacity of the committee to make administrative changes, improve technical capacity, repair and maintain infrastructure for the sources to reach their full potential.

5.2.3 Local Demand and Supply of Water

Sixty four percent of households consume less than 250 liters of water per day. The demand of water is much higher, 52.8% of households' demand is 500-1000 liters per day whereas 29.2% households' demand is 1000-1500 liters per day. The water supplied by the user committee is not enough for most households, as a result of which they use alternative sources. Total water supplied by the municipal system in Tansen is 840,000 liters per day as compared to the demand of 2,926,000 liters per day. The user committee falls short of 2,086,000 liters per day. Water demand and supply for a household was calculated to be 1045 liters and 300 liters per day respectively. Whereas, per capita demand and supply was calculated to be 283.19 liters and 81.3 liters per day respectively. With the demand-supply ratio of 3.48, it can be concluded that the user committee does not supply enough water for the livelihoods of inhabitants of Tansen. As compared to this, the water deficit in Kathmandu valley was found to be 102 million liters per day, with the per capita water demand of 135 liters per day (Udmale et al., 2016).

According to WHO (2004), the minimum amount of water needed per capita per day for short-term survival is 30 liters; it comprises water needed for drinking and cooking only. Whereas for medium term – maintaining purposes, the minimum amount of water needed per capita per day is 280 liters. This amount is equivalent to the per capita water demand which is also almost equivalent to the total daily household supply of water in Tansen. The consumption of water depends on the lifestyle and eating habits of people. Less than half the population in Palpa have access to piped drinking water supply (46.7%), and even lesser number of households with flush toilets connected to septic tanks (44.7%) (CBS, 2016).

Monthly cost of water is determined with the help of average amount of cost of water per month. A meter is used at the receiver's end (consumer's homes) to measure the amount of water that has flown through each month. Payment to the user committee at the end of the month is required. The monthly rate is NPR 100 for 18,000 liters and an additional NPR 30 for each 10,000 liters up to 28,000 liters. The additional increase of NPR 50 is applied for each 1,000 liters for up to 33,000 liters and further NPR 80 per 1,000 liters for up to 38,000 liters. But majority of respondents pay less than NPR 500 per month. The average bill is of NPR 280 (median) whereas more than 75% pay up to NPR 450 per month. The usage of water also depends on the duration of supply. 82% of households receive water for 45 minutes to 1 hour. Since Tansen is a hill-station, equitable distribution of water in all areas is a difficult task under the system of gravity flow. Also, water from all sources are not collected to a single point before supplying. Because of the geographical variation, areas nearest to the points of supply receives water for longer duration than areas that are the farthest.

The highest number of respondents use tankers as a major alternative source of water. Water from tankers are supplied from private companies. However, the use of jars for drinking water is not a common practice. Drinking water is often enough by the municipal supply source. If in case the municipal supply is less, people save it for drinking purposes and opt to other water sources for household purposes. Besides tankers, springs and public-taps are other major alternative water sources. Tansen has numerous small springs, some of which are seasonal. The smaller springs that have not been integrated into the municipal supply system is used by the nearby local people. Although the flow and amount of water is not constant, it plays an important role in meeting the water demands of local people.

In 2006, in the world, 884 million people did not have access to improved sources of drinking water, among which 207 million people were from Southern Asia. People who lacked proper sanitation were 2.5 billion, among which 1.08 billion were from Southern Asia. Per capita water consumption ranged from $4m^3$ per year in Mali to $215m^3$ per year in the USA (WBSCD, 2009). In many medium and large cities in the developing countries, households with monthly income of US$150-400 can afford piped municipal water at their homes (Nauges & Whittington, 2009). The global water consumption increased six folds during 1990-1995, and is expected to rise over the next 30 years (Every Little Drop, 2017). Large proportion of population is currently under water stress (Vorosmarty et al., 2000). In developing countries, water scarcity will be a serious problem, with decrease in amount of water available, especially in dry basins undergoing massive development in domestic and industrial sector (Rosegrant & Cai, 2002).

5.3 Institutional Structure and Governance

5.3.1 Institutional Structure

According to the Water Resources Act, 1992, Section 3 of Nepal, the right of ownership of water resources inside the territory of Nepal is conferred in Nepal. Section 5 states that people wishing to utilize a water resource may form a users' association for collective benefit. Such associations act as a corporate body having their own seal and possess the right to own, use, sell or dispose any movable or immovable property. These associations are registered in the Government of Nepal and the first priority of utilization is provided for drinking water purposes. The Water Resources Rules 1993, Chapter 3 states that the license is issued by the Water Resource Committee in each district chaired by the Chief District Officer and consists of representatives from District Agriculture Development Office, District Forest Office, District Drinking Water Office, District Irrigation Office, District Development Committee and electricity project run in the district.

Chapter 2, rule 4 of the Drinking Water Rules, 1998 requires the consumer organizations to have their own constitutions, which consist of their objectives, scope, qualification for membership and defines the composition, functions and power of general assembly.

Provisions for the meetings, elections and economic resources are defined as well. After the submission of an application by persons willing to register the consumer organization, the Water Resources Committee makes appropriate examinations and if necessary, gives the certificate of registration. The role of public agencies and stakeholders organizations such as Water User Associations, I/NGOs and academic institutions are identified by the National Water Plan. Before the Sixth Plan, development of water resources focused on sectoral use of water and did not include integrated management (National Water Plan, 2005).

Tansen's water supply system was handed over to the Tansen Drinking Water User Committee in 2010. According to the chief engineer in DWSS, "Priority ranking in handing over the water supply project is: 1. User's group. 2. Civil bodies 3. Corporation/board 4. Private sector. First priority is given to user's group because users work voluntarily hence, operation cost is reduced." The smaller maintenance works is overseen by the committee itself but larger works like development of new sources and construction works are handled by DWSS. Government of Nepal holds the right to formulate policies for the management and development of water resources. The regional office carries out monitoring and supervision and publishes reports of the evaluation. The district office of DWSS facilitates in the formation and registration of User Committees and supports them in the implementation of policies. The executive body of the user committee consists of 9 members, fulfilling the criteria defined by Chapter 2 of Drinking Water Rules to have a minimum of 9 members. Total number of consumers is 2800, in 12 wards of Tansen municipality. From each ward, a 7-member representative body is sent to the executive body, which consists of at least 1 female. Meetings in the ward level take place each month, or as peer need. Voting of the representatives is done every 3 years. Whereas, the executive members are nominated by political parties and selected by consensus from the public. The User Committee is responsible for the operational, administrative and technical works abiding to the laws of Nepal.

5.3.2 Governance

For the purpose of this study, gender has been classified as male and female, identifying their social roles. Participation was found to be higher in males than in females, although the overall number of respondents were greater in female than males. χ^2 test showed that the two variables are dependent, i.e., from the total population, males are more likely to participate in the activities of User Committee than the females. But awareness was not dependent on gender. χ^2 test did not show any association between being aware about the activities or issues of User Committee according to gender; only 25% male were aware as compared to 20% female. But the test between dependence of gender and involvement showed that more males are likely to provide suggestions to the User Committee and be involved in its affairs and issues than females.

In similar analysis of χ^2 test, it was found out that there is no association between participation and caste. Almost $2/3^{rd}$ of each caste had not participated in the activities of User Committee. Whereas, the significance between awareness and caste was high. Small p-value means that the risk of rejection of null hypothesis while it is true is very small, which implies a strong dependence between two variables. More than 90% of Magars were unaware about the issues and activities of User Committee, however interestingly, 25% of the Dalits responded that the User Committee did not have any issues at all, which shows the lack of communication between and among social groups. When it comes to providing suggestions to the User Committee, all the castes showed a better result comparatively with other variables. People are more likely to be voluntarily involved by providing suggestions to the committee than attend the formal activities.

It goes on to show that although females are equally aware as males about the issues of the committee, they are less likely to get involved or participate. Also, they don't offer their opinions and suggestions as often as male do.

But, caste of people plays an important role in determining their awareness about the committee's issues. However, all castes are equally likely to participate in the activities of the User Committee and get involved with their issues by providing suggestions. No association was found between caste and the perception of transparency, nor between gender and transparency. But attendance in the yearly general assembly plays an important role in developing perceptions about the accountability of the User Committee. Regardless of the gender and caste, if a person has attended a yearly assembly meeting, they're more likely to have positive perception and more likely to think that the committee is accountable to its consumers.

Water users' associations for irrigation in Nepal are almost exclusively controlled by male executive body. Very few women are in the position with decision making powers, to combat with which, a quota system of minimum number of women participation is implied (Berry & Mollard, 2010). The same rule applies to TDWUC, which requires a minimum of 33% women involvement in the executive domain. But despite the rule, only 1 out of 9 members is a female. Gender issues are deemed important for good governance (Broody, 2009). Increased participation of women could lead to an increase in their "bargaining position as resource users" and increase in the efficiency of the organization by making women more aware about their rights and duties (Meinzen-Dick & Zwarteveen, 1998). The worldwide data suggests that when it comes to national parliaments, 23.5% consists of women. In Asia, the percentage of women is only 19.4% (IPU, 2017). Gender inclusive governance is the means to change social norms and ensure that the voice of women is addressed in the decision making processes (Broody, 2009). Many drinking water supply systems have been unsuccessful in Nepal because of lack of involvement of women (World Water Assessment Programme, 2003). Whereas, in case of forest management in Nepal, it has been observed that groups with higher participation of female as executive members have better forest governance, with better regeneration and canopy growth (Agrawal, 2009).

A similar study on the common pool resources in the Terai region of Nepal found that, the participation in community user groups is more in socially and economically strong people (Agrawal & Gupta, 2005). The study also showed that people who had greater access to the government offices and kept contact with government officials were more likely to be a part of such groups, concluding that efficient decentralization requires the institutional framework to be more inclusive of the marginalized groups (Agrawal & Gupta, 2005). Considering water governance, it is generally presumed that including minority groups in management process will itself lead to an equity in water rights and ultimately good governance, but in reality securing equitable water rights for marginalized people is more complicated than participation (Cleaver & Hamada, 2010).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The study showed that the yearly average temperature showed an increasing trend of (0.087°C per year) in Palpa district, but the rainfall pattern did not show a significant trend. Although the groundwater recharge did not show any significant trend, the rate of decrease of groundwater recharge through rainfall was found to be 1.66mm/year. Various scientific studies in the past have shown that there is no exact estimation of the effects of climate change on groundwater; most studies suggest that change in climatic phenomenon won't lead to a decrease in groundwater. However, under the pressure of growing population and increasing demand for water, the extraction of groundwater is likely to increase. Also, increased temperature will increase evaporation and transpiration processes, thereby reducing the amount of water that infiltrates into the ground.

Per capita water demand for Tansen was calculated to be 283.19 liters per day and supply was calculated to be 81.3 liters per capita per day. The total daily water supply for Tansen municipality is 840,000 liters per day as compared to the demand of 2,926,000 liters per day. Five of the major spring-water sources supply water to the municipality through TDWUC. Other smaller sources are used on regular basis by locals. Lack of management and protection of water sources, insufficient financial and technical capacities and incompetent pricing mechanisms are identified as the major causes of the water scarcity in Tansen.

TDWUC has been registered with the government following the Water Resource Act. It has its own rules to abide by, besides the rights and responsibilities conferred upon it by the government. The government support is provided for technical and infrastructure development on request, although there is not adequate transparency in communication about the rules, regulations and processes of the user committee. The committee follows both top-down and bottom-up approach and encourages participation through the elected ward representatives. However, gender and caste play an important role in participation, involvement, perception and awareness.

The study concludes that the effects of climate change in Tansen are certain but their impacts on groundwater cannot be established with confidence. The town faces water scarcity currently, which could get worse if proper managerial actions are not implemented on time.

6.2. Recommendations

Following are some recommendations:

Table 14: Recommendations

Area	Recommendations
Water Demand and Supply Management	• Spring revival programs might be implemented in the spring sources that are at the threat of drying up. • Water collection ponds or tanks could be established near the spring-water sources to collect the freely flowing water to use it in time of need. • At the local level, promoting rainwater harvesting at household and community level could be done to increase groundwater recharge.
Administrative and Policy Level	• Role and functions of some organizations (especially those responsible for policy making) might be refined for an integrated approach in the management of water resources rather than sectoral management. • Rules, regulations and policies could be better communicated to the users to make them aware about their user rights and responsibilities.
Local Governance	• Locals could be encouraged to participate in the activities of the User Committee to increase their level of awareness about the issues and activities of the committee for the conservation and management of water resources. • Technical enhancement and capacity building in the lower levels could be implemented to strengthen the ability of User Committee to be more efficient.
Scope for Research	• In depth researches on hydrology, geology, geochemistry and socioeconomic aspects of water supply should be done in future to better understand water scarcity and to comprehend the exact impacts of climate change on groundwater.

REFERENCES

Acharya, A. (2015). The Cultural Politics of Waterscapes. In R. L. Bryant, *The International Handbook of Political Ecology* (pp. 373-386).

Agrawal, A., & Gupta, K. (2005). Decentralization and Participation: The Governance of Common Pool Resources in Nepal's Terai. *World Development, 33*, 1101–1114.

Agarwal, B. (2009). Gender and forest conservation: The impact of women's participation in community forest governance. *Ecological economics, 68*(11), 2785-2799.

Agrawala, S., & Aalst, M. V. (2008). Adapting Development Coopration to Adapt to Climate Change. *Climate Policy, 8*, 183-193.

APN. (2007). *Enhancement of National Capacities in the Application of Simulation Models for the Assessment of Climate Change and its Impacts on Water Resources and Food, and Agricultural Production.* Final Report of APN CAPaBLE project, 2005-CRP1CMY-Khan.

Asian Development Bank. (2009). *Building Climate Resilience in the Agriculture Sector of Asia and the Pacific.* Mandaluyong, Phillipines: Asian Development Bank and International Food Policy Research Institute.

Babel, M. S., Gupta, A. D., & Pradhan, P. (2007). A Multivariate Econometric Approach for Domestic Water Demand Modeling: An Application to Kathmandu, Nepal. *Water Resource Management, 21*, 573–589.

Bajracharya, T. R., Acharya, S., & Ale, B. B. (2011). Changing Climatic Parameters and its Possible Impacts in Hydropower Generation in Nepal (A Case Study on Gandaki River Basin). *Journal of the Institute of Engineering, 8*(1-2), 160–173.

Bandyopadhyay, J., & Gyawali, D. (1994). Himalayan Water Resources: Ecological and Political Aspects of Management. *Mountain Research and Devlopment*, 1-24.

BCAS . (2005). *Adverse Impacts of Climate Change on Development of Nepal: Integrating Adaptation Into Policies and Activities.* Dhaka, Bangladesh: Bangladesh Centre for Advanced Studies.

Berry, K., & Mollard, E. (Eds.). (2009). *Social participation in water governance and management: critical and global perspectives*. Taylor & Francis.

Beuhler, M. (2003). Potential Impacts of Global Warming on Water Resources in Southern California. *Water Science and Technology, 47*(7-8), 165-168.

Bhandari, B., & Grant, M. (2007). User Satisfaction and Sustainability of Drinking Water Schemes in Rural Communities of Nepal. *Sustainability: Science, Practice and Policy, 3*, 12-20.

Bricker, S. H., Yadav, S. K., Macdonald, A. M., Satyal, Y., Dixit, A., & Bell, R. (2014). *Groundwater resilience Nepal: Preliminary findings from a case study in the Middle Hills*. British Geological Survey.

Brody, A. (2009). *Gender and governance: Overview report*. University of Sussex. Institute of development studies (IDS). BRIDGE.

Brouyere, S., Carabin, G., & Dassargues, A. (2004). Climate Change Impacts on Groundwater Resources: Modelled Deficits in a Chalky Aquifer, Green Basin, Belgium. *Hydrology, 12*(2), 123-134.

CBS. (2011). *National Population and Housing Census.* Kathmandu: Government of Nepal, National Planning Commission Secretariat.

CBS. (2014). *Statistical Pocketbook of Nepal.* Kathmandu, Nepal: Government of Nepal, National Planning Commission.

CBS. (2016). *Annual Household Survey 2014/15 (Major Findings).* Kathmandu: Government of Nepal, National Planning Commission Secretariat.

Chaturvedi, R. S. (1973). *A Note on the Investigation of Groundwater Resources in Western Districts of Uttar Pradesh.* 1973: Annual Report, UP Irrigation Research Institute.

Chen, X., & Chen, X. (2004). Simulating the Effects of Reduced Precipitation on Groundwater and Streamflow in Nebraska Sand Hills. *Journal of the American Water Resources Association, 40*(2) , 419-430.

Chen, Z., Grasby, S. E., & Osadetz, K. G. (2004). Relation Between Climate Variability and Groundwater Levels in the Upper Carbonate Aquifer, Southern Manitoba, Canada. *Journal of Hydrology, 290*(1), 43-62.

Cleaver, F., & Hamada, K. (2010). 'Good' water governance and gender equity: a troubled relationship. *Gender & Development, 18*(1), 27-41.

DeNeufville, J. I., & Barton, S. E. (1987). Myths and the Definition of Policy Problems - An Exploration of Home Ownership and Public-Private Partnerships. *Policy Sciences, 20*(3), 181-206.

DHM. (2009). *Dry and Warm Winter 2009.* Kathmandu: Department of Hydrology and Meterology, Government of Nepal.

Doll, P. (2009). Vulnerability to the Impact of Climate Change On Renewable Groundwater Resources: A Global-Scale Assessment. *Environmental Research Letters, 4*(3), 035006.

Doll, P., & Florke, M. (2005). Global-Scale Estimation of Diffuse Groundwater Recharge. *Frankfurt Hydrology Paper 03*.

Every Little Drop. (2017, July 26). *Water Consumption Around the World*. Retrieved from Every Little Drop: http://everylittledrop.com.au/knowledge-center/water-consumption-around-the-world/

Gleeson, T., Befus, K. M., Jasechko, S., Luijendijk, E., & Cardenas, M. B. (2016). The Global Volume and Distribution of Modern Groundwater. *Nature Geoscience, 9*(2), 161-171.

GWP. (2002). *Effective Watr Governance.* Glpbal Water Partnership.

Goswami, B. N., Venugopal, B., Sengupta, D., Madhusoodanan, M. S., & Xavier, P. K. (2006). Increasing Trend of Extreme Rain Events Over India in a Warming Environment. *Science*, 1442-1445.

Green, T. R., Taniguchi, M., Kooi, H., Gurdak, J. J., Allen, D. M., Hiscock, K. M., . . . Aureli, A. (2011). Beneath the Surface of Global Change: Impacts of Climate Change on Groundwater. *Journal of Hydrology, 405*(3), 532–560.

Hanjra, M. A., & Qureshi, M. E. (2010). Global Water Crisis and Future Food Security in an Era of Climate Change. *Food Policy, 35*, 365-377.

Hansen, A., & Lebedeff, S. (1987). Global Trends of Major Surface Air Temperature . *Journal Geophysical Research, 92*, 13345-13372.

HI-AWARE. (2017). *The Upper Ganga Basin - Will Drying Springs and Rising Floods Affect Agriculture.* Kathmandu, Nepal: HI-AWARE Consortium Secretariat.

Holman, I. P. (2006). Climate Change Impacts on Groundwater Recharge- Uncertainty, Shortcomings and the Way Forward? *Hydrogeology Journal, 14*(5), 637-647.

ICWE. (1992). *The Dublin Statement on Water and Sustainable Development*. Retrieved from World Meterological Organization: http://www.wmo.int/pages/prog/hwrp/documents/english/icwedece.html

IPCC. (1992). *Climate Change 1992 - The Supplementary Report to the IPCC Impacts Assesment.* Canberra: Australian Government Publishing Service.

IPCC. (2001a). *Climate Change 2001: Synthesis Report.* Cambridge: Cambridge University Press, Intergovernmental Panel on Climate Change.

IPCC. (2001b). *Climate Change 2001: Impacts, Adaptation and Vulnerability - Contribution of Working Group II to the Third Assessment Report of IPCC.* Intergovernmental Panel on Climate Change.

IPCC. (2007). *Climate Change 2007: Synthesis Report.* IPCC.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis.* Cambridge, United Kingdom and New York, USA: Cambridge University Press.

IPCC. (2014a). *Climate Change 2014 Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* New York, USA: Cambridge University Press.

IPCC. (2014b). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland: Intergovernmental Panel on Climate Change.

IPU. (2017, July 1). *Women in National Parliaments*. Retrieved from International Parliamentary Union: http://www.ipu.org/wmn-e/world.htm

Jyrkama, M. I., & Sykes, J. F. (2007). The Impact of Climat Change on Spatially Varying Groundwater Recharge in th Grand River Watershed. *Journal of Hydrology, 338*(3), 237-250.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2010). The Worldwide Governance Indicators: Methodology and Analytical Issues. *Hague Journal on the Rule of Law*, 220-246.

Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement, 30,* 607-610.

Kumar, C. P., & Seethapathi, P. V. (2002). Assessment of Natural Groundwater Recharge in Upper Ganga Canal Command Area. *Journal of Applied Hydrology, 15*, 13-20.

Larson, A. M. (2003). Decentralisation and Forest Management in Latin America: Towards a Working Model. *Public Administration and Development, 23*(3), 211-226.

Larson, A. M., & Soto, F. (2008). Decentralization of Natural Resource Governance Regime. *Annual Review of Environment and Resources*, 213-239.

L'vovich, M. I. (1979). *World Water Resorces and their Future* . Michigan: American Geophysical Union.

Meinzen-Dick, R., & Zwarteveen, M. Z. (1998). Gendered Participation in Water Management: Issues and Illustrations From Water Users' Associations in South Asia. *Agriculture and Human Values, 15*, 337–345.

Meixner, T., Manning, A.H., Stonestrom, D.A., Allen, D.M., Ajami, H., Blasch, K.W., Brookfield, A.E., Castro, C.L., Clark, J.F., Gochis, D.J. and Flint, A.L., 2016. Implications of projected climate change for groundwater recharge in the western United States. *Journal of Hydrology, 534*, 124-138.

Mekonnen, M. M., & Hoekstra, A. Y. (2011). *National Water Footprint Accounts: The Green, Blue and Grey Water Footprints of Production and Consumption, Value of Water Research Report Series No. 50.* UNSCO-IHE.

MoE. (2010a). *Climate Change Vulnerability Mapping for Nepal - National Adaptation Programme of Action (NAPA) to Climate Change.* Kathmandu: Government of Nepal, Ministry of Environment.

MoE. (2010b). *National Adaptation Programme of Action to Climate Change.* Kathmandu, Nepal: Government of Nepal, Ministry of Environment.

National Planning ommission. (2016). *14th Plan.* Kathmandu: Government of Nepal, National Planning Commission.

National Water Plan. (2005). *National Water Plan - Nepal.* Kathmandu: Government of Nepal.

Nauges, C., & Whittington, D. (2009). Estimation of water demand in developing countries: An overview. *The World Bank Research Observer, 25*(2), 263-294.

NCVST. (2009). *Vulnerability Through the Eyes of Vulnerable: Climate Change Induced Uncertainties and Nepal's Development Predicaments.* Kathmandu: Institute for Social and Environmental Transition-Nepal (ISET-N, Kathmandu) and Institute for Social and Environmental Transition (ISET, Boulder, Colorado) for Nepal Climate Vulnerability Study Team (NCVST).

OECD. (2003). *Development and Climat Change in Nepal: Focus on Water Resources and Hydropower.* Paris, France: Organisation for Economic Cooperation and Development.

OECD. (2012). *OECD Environmental Outlook to 2050.* Organisation for Economic Cooperation and Development.

OECD. (2015). *OECD Principles on Water Governance.* Directorate for Public Governance and Territorial Development.

Pahl-Wostl, C., Holtz, G., Kastens, B., & Knieper, C. (2010). Analyzing Complex Water Governance Regimes: The Management and Transition Framework. *Environmental Science and Policy, 13*, 571-581.

PAN. (2009). *Temporal and Spatial Variability of Climate Change Over Nepal (1976-2005).* Kathmandu: Practical Action Nepal.

Pereira, L. S., Cordery, I., & Iacovides, I. (2002). *Coping With Water Scarcity.* Paris: UNESCO.

Poudel, D. D., & Duex, T. W. (2017). Vanishing Springs in Nepalese Mountains: Assessment of Water Sources, Farmers' Perceptions, and Climate Change Adaptation. *Mountain Research and Development, 37*, 35-46.

Rogers, P., & Hall, A. W. (2003). *Effective Water Governance.* Sweden: Global Water Partnership.

Rosegrant, M. W., & Cai, X. (2002). Global water demand and supply projections: part 2. Results and prospects to 2025. *Water International, 27*(2), 170-182.

Shiklomanov, I. (1993). World Fresh Water Resources. In P. H. Gleick, *Water in Crisis: A Guide to the World's Fresh Water Resources.*

Shrestha, A. B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum Temperature Trends in the Himalaya and Its Vicinity: An Analysis Based on Temperature Records from Nepal for the Period 1971–94. *Journal of Climate, 12*, 2775-2786.

Shrestha, A. B., Wake, C. P., Dibb, J. E., & Mayewski, P. A. (2000). Precipitation Fluctuations in the Nepal Himalaya And Its Vicinity And Relationship With Some Large Scale Climatological Parameters. *International Journal of Climatology, 20*, 317-327.

Shrestha, M. L., & Shrestha, A. B. (2005). *OECD.* Retrieved from OECD.org: http://www.oecd.org/env/cc/33993644.pdf

Synott, P. (2012). *Climate Change, Agriculture and Food Security In Nepal.* Mercy Corps Nepal.

Taylor, R. G., Scanlon, B., Doll, P., Rodell, M., Beek, R. V., Wada, Y., Longuevergne, L., Leblanc, M., Famiglietti, J. S., Edmunds, M., Konikow, L, Gurdak, J. J. (2012). Groundwater and Climate Change. *Nature Climate Change, 3*(4), 322.

Udmale, P., Ishidaira, H., Thapa, B. R., & Shakya, N. M. (2016). The status of domestic water demand: supply deficit in the Kathmandu Valley, Nepal. Water, 8(5), 196.

UNCED. (1992). *United Nations Sustainable Development.* Rio Di Janerio, Brazil: United Nations Conference on Environment and Development.

UNDP. (1997). *Governance for Sustainable Human Development - A UNDP Policy Document.*

UNESCO. (2004). Groundwater Resources of the World And Their Use. (I. S. Zektser, & L. G. Everett, Eds.) Paris: UNESCO. Retrieved from http://unesdoc.unesco.org/images/0013/

United Nations Population Division. (2015, July 29). *World Population Prospects: The 2015 Revision*. Retrieved from United Nations Population Fund: http://www.unfpa.org/world-population-trends

Vorosmarty, C. J., Green, P., Salisbury, J., & Lammers, R. (2000). Global Water Resources: Vulnerability from Climate Change and Population Growth. *Science, 289*(5477), 284-288.

Water Footprint Network. (2017, July 29). *Water Footprint of Nations*. Retrieved from Water Footprint: http://temp.waterfootprint.org/?page=files/WaterFootprintsNations

Water Governance Facility. (2017, July 17). *What is Water Governance?* Retrieved from Water Governance: http://watergovernance.org/governance/what-is-water-governance/

WBSCD. (2009). *Water Facts and Trends.* World Business Council for Sustainable Development.

World Health Organization. (2004). *Minimum Water Quantity Needed for Domestic Uses.* New Delhi, India: WHO Regional Office for South-east Asia.

World Water Assessment Programme. (2003). *Water for People, Water for Life.* New York: UNESCO.

ANNEX I: SCHEDULE SURVEY QUESTIONNAIRE

I am Ashmita Paudel, a student of Central Department of Environment Science, Tribhuvan University. This questionnaire is being used to extract information for my research work “Water Availability under Climate Stress in a Hilly Settlement of Nepal: A Case Study from Tansen, Palpa”. I request for your kind cooperation and help me carry out my research by answering these questions. Any information given by you will be used only for academic purposes and will remain confidential.

Part 1: Personal Details

Name:……………………………………………………………………………………………………

Age: …………………………. Gender: □ Male □ Female □ Other

Ward no: ………………….. Household size: ……………………..

Occupation: ……………………………………………………………………………………………………

Part 2: Water Availability

1. How long have you lived in Tansen?

……………………………………………………………………………………………………

2. Are you a consumer of Tansen Drinking Water User’s Committee?

□ Yes □ No

3. What is your source of drinking water?

□ Committee’s supply system □ Public taps

□ Springs/Rivers □ Tanker/Jar water

□ Others (specify) ……………………………….

4. What is your source of water for other uses?

□ Committee’s supply system □ Public taps

□ Springs/Rivers □ Tanker/Jar water

□ Others (specify) ……………………………….

5. How much water do you consume per day? (Measure of vessels, buckets or jars, in liter)

………

6. How much is your water demand per day? (In liters)

………..

7. How often do you get water in your home, from the committee supply?

………

8. How long do they provide water (in hours)?

………

9. Is that enough for your uses?

□ Yes □ No

10. Do you use alternative ways to meet your water demands? (Eg: tankers, jars, other sources) If yes, what do you prefer?

……

11. How often do you bring water from other sources?

□ Daily □ Weekly □ Once in 2 weeks □ Monthly

□ Based on seasonal water demand □ Others (specify)………………………………………

12. In your family, who goes to carry/bring water? ………………………………………………………..

13. How much do you pay to the committee per month (on average)?

………

14. How many tankers and jars do you buy per month?

In dry season: ……………………………………………………………

Other seasons: …………………………………………………………..

15. How much do you pay for other sources (like tankers and jars)?

In dry season: ……………………………………………………………….

Other seasons: ………………………………………………………………

16. Can you easily get access to these alternative sources during dry season?

□ Yes □ No

17. Do you have a storage tank?

□ Yes □ No

18. What is the capacity of your storage tank?

………..

19. Do you use a motor to pump water in your tank?

□ Yes □ No

20. Do you need extra water for your occupation?

□ Yes □ No

21. Do you have rain water harvesting ,a well or your own spring water source?

□ Yes □ No

22. What is your source of water for agriculture? Kitchen garden?

………

Part 3: Governance

1. Is anyone from your household an executive member of the user committee?

□ Yes □ No

2. Have you ever attended the yearly general assembly meeting?

□ Yes □ No

3. Are you aware of the issues of the user committee?

□ Yes □ No

4. Have you been invited to or attended any of the special consultation meetings?

□ Yes □ No

5. Do you vote for the committee member selection?

□ Yes □ No

6. If no, do you have any complaints with this?

□ Yes □ No

7. How responsive is the committee to your complaints and issues?

□ Very responsive □ Responsive □ Not very responsive □ Indifferent

8. Have you ever provided any suggestions to the committee?

□ Yes □ No

9. If yes, briefly explain what kind of suggestion?

……
…………………………………………………….

10. If yes, have they taken it under consideration?

□ Yes □ No

11. Is the budget presented during general assembly?

□ Yes □ No

12. Do you think the committee is transparent about its expenses?

□ Yes □ No

13. Are you aware of the costs of operating the water supply systems?

□ Yes □ No

14. Is the water supplied regularly?

□ Yes □ No

15. Is there a specific time of day/week?

□ Yes □ No

16. Do you feel that the water is supplied equally to all parts of Tansen?

□ Yes □ No

17. If there is any issue with the supply system, are you informed about it?

□ Yes □ No

18. How does the committee inform you about important notices?

□ Newspapers □ FM/Radio □ Local Television □ Call for meetings

□ Word-of-mouth □ Others (Specify)……………………………………………

Part 4: Perception of Climate Change

1. Which were the warmest and coldest months 20 years ago?

Warm months:

……………………………………………………………………………………………………

Cold months:

………………………………………………………………………………………………………

2. Which are the warmest and coldest months now?

Warm months:

……………………………………………………………………………………………………

Cold months:

………………………………………………………………………………………………………

3. Which months did you use to have rainfall 30 years ago?

Pre-monsoon:

…………………………………………………………………………………………………

Monsoon:

…………………………………………………………………………………………………

4. Which months do you have rainfall now?

Pre-monsoon:

…………………………………………………………………………………………………

Monsoon:

…………………………………………………………………………………………………

5. Are you aware of any incidence in Tansen where springs have dried?

□ Yes □ No

If yes, how many? ……………………………………………………………..

Did you depend on any of these sources for water? □ Yes □ No

6. Has the number of seasonal springs increased or decreased or remained same over the years?

□ More □ Less □ Similar

The following are to be asked comparing the situation of 20 years ago with now

S.N.	Questions about Climate Change	Categories			
		No Change	Increased	Deceased	Not valid
1	Summer temperature				
2	Winter temperature				
3	Monsoon rainfall				
4	Pre-monsoon rainfall				
5	No. of dry days				
6	Water availability for crops and animals				
7	Occurrence of sickness in people due to weather change				
8	Drying up of fresh water sources				
9	Crop productivity				
10	Livestock productivity				
11	Natural hazards				

ANNEX II: FOCUS GROUP DISCUSSIONS

Focus Group Discussion

Jan 2017

2073|10|03
17th Jan, 2017

Tansen Drinking Water User's Committee, Tansen, Municipality

(1)

S.No	Name	Organization/ Ward no	Contact no	Signature
1.	Chakor Man shakya.	Chairman	9847029357	
2.	Keshab Paudel	Secretory	9857062565	
3.	Chandra Kanta Gyawali	Co-ordinator	9857033122	
4.	Thakur Prasad Lohagun	Water (member) consumer	9847028471	
5.	Pratikshya Sinjali	Water (member) consumer	9847102849	
6.	Bishnu Paudel	Tansen Municipality	9857062562	
7.	Bhimsen Karki	Treasurer	9857060305	
8.	Jhabilal Kharal	word no. 7, co-ordinator	9857060034	
9.	Krisha Kumari Thapa	Member	9847043798	
10.	Narayan Rayamajhi	Khurtung, Co.ordinator	9847567890	
11.	Naramati Singjali	Assistant secretory	9847068779	
12.	Shailendra Bhattarai	Palpa Chamber Tansen	9857060088	
13.	Bhuwasher Gyawali	staff	9847100452	
~~14.~~				—
~~15.~~				—
~~16~~				—

18th Jan 2017

Kunsare Kajipauwa, Prabhash, Tansen, Municipality

(3)

S.No	Name	Organization/ Ward no	Contact no	Signature
1.	Rajendra Laxmi Gaire		9857065255	[illegible]
2.	Mahesh Panta		9847029900	[illegible]
3.	Hari Pandey		9857062321	[illegible]
4.	Laxman Paudel	Consumer	9857060450	[illegible]
5.	Jamuna Prasad Bhattarai	Consumer	9847099875	[illegible]
6.	Yam Bahadur G.C.	Consumer	9847069360	[illegible]
7.	Lalchan Sharma	~~Member~~ Consumer	9847099899	[illegible]
8.	Maheshwor Sapkota	Consumer	9847176630	[illegible]
9.	Bishnu Nelupane	Consumer	9857060594	Bishe
10.	Tulsha Pandey	Consumer	9847099951	[illegible]
11.	Kamala Ghimire	consumer	9847218651	[illegible]
12.	Ramesh G.C.	Staff	9847068068	[illegible]
13.	हिमलाल पंथी.	[illegible]	९८२६०८०९०९	[illegible]
14.	Bishnu Gaire	member	9847029549	[illegible]
15.	Hari Kala G.C.	Member	9847099188	Hari
16.	Nanda Lal Pandey	consumer	9847118415	[illegible]
17.	Gokarna Kharel	Department of water	985109585[illegible]	[illegible]

Focus Group Discussion on Adapt...

18th Jan 2017

Bartung, Tansen, Municipality

(2)

S.No	Name	Organization/ Ward no	Contact no	Signature
1.	Bidhan Shrestha	Chairman	9847043283	[signature]
2.	Daya Ram Pandey	Vice-Chairman	9857025731	[signature]
3.	Shrawon Kumar Shrestha	Treasurer	9847128100	[signature]
4.	Shanta Karki	Member	9867112580	[signature]
5.	Kiran Kaushal	Consumer	9857060907	[signature]
6.	Dil Bahadur Dungana	Adviser	9857060017	[signature]
7.	Sushil Shrestha	Member	9847099543	[signature]
8.	Purna Prasad Ghimire	Secretary	9857060544	[signature]
9.	Tek Raj Karki	Member	9867035671	[signature]
10.	Madhu Karki	Staff	9847235699	[signature]
11.	Badri Bhattarai	Member	9847043156	[signature]
12.	Laxmi Prasad Basnet	Member.	[illegible]	[signature]
13.	Bimala Dhungana	Member.	9867244348	[signature]
14.				2001-
15.				2001-

19th Jan 2017

Basanta pu., Tansen, Municipality

S.No	Name	~~Organization~~/ Ward no	Contact no	Signature
1	Sharda Karmacharya	Ta.Na.Pa. 4	9847068018	[illegible]
2	Aarati Khati	Ta.Na.Pa. 7	9860619137	[illegible]
3	Resham Paudel	Ta.Na.Pa. 10	9847116708	रेशम
4	Sabitra Magar.	Ta.Na.Pa. 6	9867136985	सावित्रा
5	Kamala Somai	Ta.Na.Pa. 14	9847419671	कमला सोमै
6	Sabitri Gautam	Ta.Na.Pa. 8	9847100179	सावित्री
7	Sangita Sonam	Ta.Na.Pa. 8	9847002979	संगीता
8	Manisara Thapa	Ta.Na.Pa. 2	9847423732	[illegible]
9	Menakumari Bhat	Ta.Na.Pa. 13	9847069922	मेना
10	Sharda Khanal	Ta.Na.Pa. 3	9847438474	Shy.
11	Pabitra Khanal	Ta.Na.Pa. 11	9844706741	पवित्रा
12	Indramaya Sharma	Ta.Na.Pa. 5	9867017326	इन्द्रमाया शर्मा
13	Laxmi Pandey	Ta.Na.Pa. 9	9847231258	लक्ष्मी
14	Basanti Bashyal	Ta.Na.Pa. 12	9847772770	बसन्ती
15	Raju B.K.	Ta.Na.Pa. 12	9847308650	राजु

ANNEX III: PHOTOGRAPHS

Photo 1: Focus Group Discussion with Women's Group

Photo 2: An Almost Dry Stone Spout

Photo 3: Focus Group Discussion with TDWUC

Photo 4: Conduction of Household Survey

Photo 5: Infrastructure of Sisne Water Supply System

Photo 6: Key Informant Interview with Chief Engineer, DWSS, Palpa

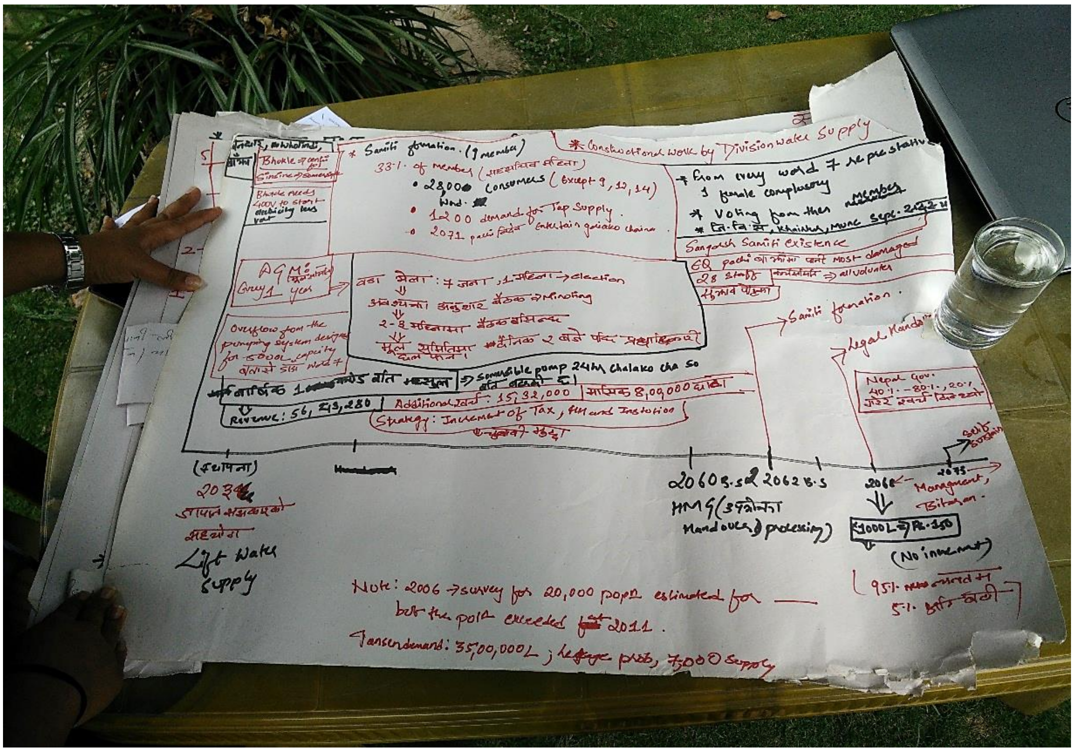

Photo 7: FGD Activity: Institutional Mapping

Photo 8: GPS Points Collection

Photo 9: Collection from Sisne Source

Photo 10: Consumers Waiting to Pay Their Bills in TDWSS Office

Photo 11: KII with the Chairman of TDWSS

Photo 12: KII with the Caretaker of Teendhara Source

Photo 13: New Storage Tank under Construction

Photo 14: Women Waiting for Their Turn to Fetch Water